

# THE AUSTRALIAN Entomologist

*published by*  
THE ENTOMOLOGICAL SOCIETY OF QUEENSLAND



Volume 34, Part 4, 10 December 2007

Price: \$6.00 per part

ISSN 1320 6133



## THE AUSTRALIAN ENTOMOLOGIST

ABN#: 15 875 103 670

The Australian Entomologist is a non-profit journal published in four parts annually by the Entomological Society of Queensland and is devoted to entomology of the Australian Region, including New Zealand, Papua New Guinea and islands of the south-western Pacific. Articles are accepted from amateur and professional entomologists. The journal is produced independently and subscription to the journal is not included with membership of the society.

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**Cover:** *Parobia alipilus* Seeman & Nahrung (Podapolipidae) is one of three sexually-transmitted mites that infest the eucalyptus leaf beetle *Paropsis atomaria*. The adult male (pictured) is unlike the female: his legs have spurs, the genital capsule is mid-dorsal and the fourth pair of legs is modified. Nevertheless, *Parobia* species are among the most mite-like of the Podapolipidae, where physogastry and loss of legs is common and some males have their genitalia on prongs above their heads. *Parobia* mites are often more common on female beetles and at least one species significantly reduces survival of the host during overwintering. Illustration by Owen Seeman.



# **DISTINGUISHING BETWEEN LYNX SPIDERS (ARANEAE: OXYOPIDAE) RELEVANT TO IPM IN COTTON IN THE NAMOI VALLEY, NEW SOUTH WALES**

M.E.A. WHITEHOUSE<sup>1</sup> and J.F. GRIMSHAW<sup>2</sup>

<sup>1</sup>CSIRO Entomology, Australian Cotton Research Institute, Locked Bag 59, Narrabri, NSW 2390 (Email: mary.whitehouse@csiro.au)

<sup>2</sup>PO Box 1356, Toowong, Qld 4066 (Email: grimshawjudy@hotmail.com)

## **Abstract**

Characters are presented to enable identification of three similar species of lynx spiders (*Oxyopes molaris* L. Koch, *Oxyopes amoenus* L. Koch and *Oxyopes gracilipes* (White)) commonly found in cotton in northern New South Wales. The aim is to enable non-specialists to readily distinguish between these species so that they can be better incorporated within an Integrated Pest Management (IPM) framework.

## **Introduction**

The advent of transgenic Bt cotton has had a major impact on the cotton industry by largely controlling lepidopteran pests, with little effect on the rest of the insect community (Whitehouse *et al.* 2005, Hagerly *et al.* 2005). This has made cotton more amenable to Integrated Pest Management (IPM) strategies (Fitt and Wilson 2000, Deutscher *et al.* 2005) and has led to a drop in the amount of insecticide used on cotton (Fitt 2004), which has had major benefits to the community.

However, one consequence of reduced insecticide use is that minor pests, that were once controlled by sprays for *Helicoverpa* Hardwick spp. (Lepidoptera: Noctuidae), have become major pests in cotton. One such group of pests are the green and brown mirids *Creontiades dilutus* (Stål) and *Creontiades pacificus* (Stål) (Hemiptera: Miridae) respectively. In Bollgard® II cotton, the need to control mirids and other sucking pests, such as the green vegetable bug *Nezara viridula* (Linnaeus) (Hemiptera: Pentatomidae), tends to undermine the gains in reduced insecticide use that came with Bt cotton. This is because the broad-spectrum insecticides used to control these pests could disrupt the beneficial arthropods and increase the risk of secondary pest outbreaks such as mites and aphids.

One means of controlling mirids without resorting to insecticide spray, is to maintain or increase the numbers of predators in cotton that are likely to attack them. One of the main groups of predators in cotton are spiders, which make up 50% of the beneficial arthropod community in unsprayed cotton crops in Australia (Bishop and Blood 1981). Although little is known about the exact role that spiders play in the management of pests in cotton, it is known that lynx spiders (Oxyopidae) are mirid predators (Bishop and Blood 1981, Young and Lockley 1986, Nyffeler *et al.* 1992). They are also the most abundant family of spiders in Australian cotton (Whitehouse *et al.* in press). The dominance of lynx spiders in Australian cotton fields indicates that this family could be effective against mirids.

In order to utilize specific oxyopid species within an IPM framework for the control of pests, there is a need to be able to distinguish between species. However, as is the case with many Australian spider families, there are no recent revisions of the Oxyopidae. The last published work was a catalogue (Roewer 1954) that listed 14 Australian species, 12 of which were in the genus *Oxyopes* Latreille. Since then only a few papers have been published. Grimshaw (1989) reported the first record of another genus, *Hamataliwa* Keyserling, in Australia. Vink and Sirvid (1998, 2000) provided reports on *O. gracilipes* (White), but identification of specimens from their work was not possible. Townsend *et al.* (2001) provided good descriptions of some Australian Oxyopidae, but from that work it is still not possible to confidently identify a specimen at hand. To date there is only one revisional work on Australian Oxyopidae, an unpublished thesis by Grimshaw (1991).

The aim of this paper is to provide simple tools to differentiate between the three species of Oxyopidae commonly found in cotton in the Namoi Valley of northern New South Wales. By aiding species identification of these spiders, we hope to facilitate their use within an IPM framework for the control of insect pests.

### Materials and methods

Oxyopidae were collected using beatsheets (Mansfield *et al.* 2006) or visual searches throughout cotton growing seasons at the Australian Cotton Research Institute (30°11'S, 149°33'E) at Narrabri, NSW. During the 2006/07 cotton growing season, samples of 10 beatsheets on 10 sampling dates were taken throughout the season. All lynx spiders in the samples were sorted to species. Three species were found (Figs 1-8): *Oxyopes molarius* L. Koch ('plain brown lynx'), *Oxyopes amoenus* L. Koch ('banded lynx') and *Oxyopes gracilipes* (White) ('stocking lynx').

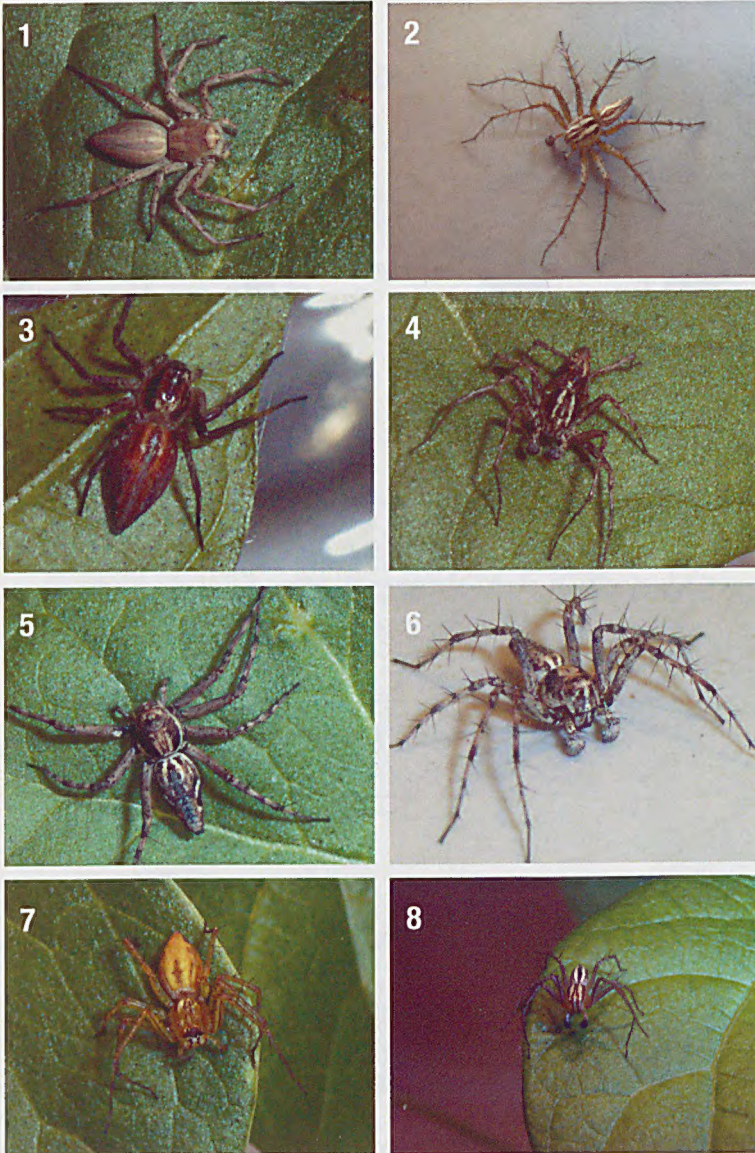
Adult specimens were identified using the key to species in Grimshaw (1991) and through comparisons with specimens held at the Queensland Museum, which had been verified by comparison with type material held in Hamburg, Germany. Voucher specimens of each species are lodged with the Queensland Museum (female *O. molarius*: QMS 83346; male *O. molarius*: QMS 83278; female *O. amoenus*: QMS 83277; male *O. amoenus*: QMS 83276; female *O. gracilipes*: QMS 83347; male *O. gracilipes*: QMS 83279).

### Results

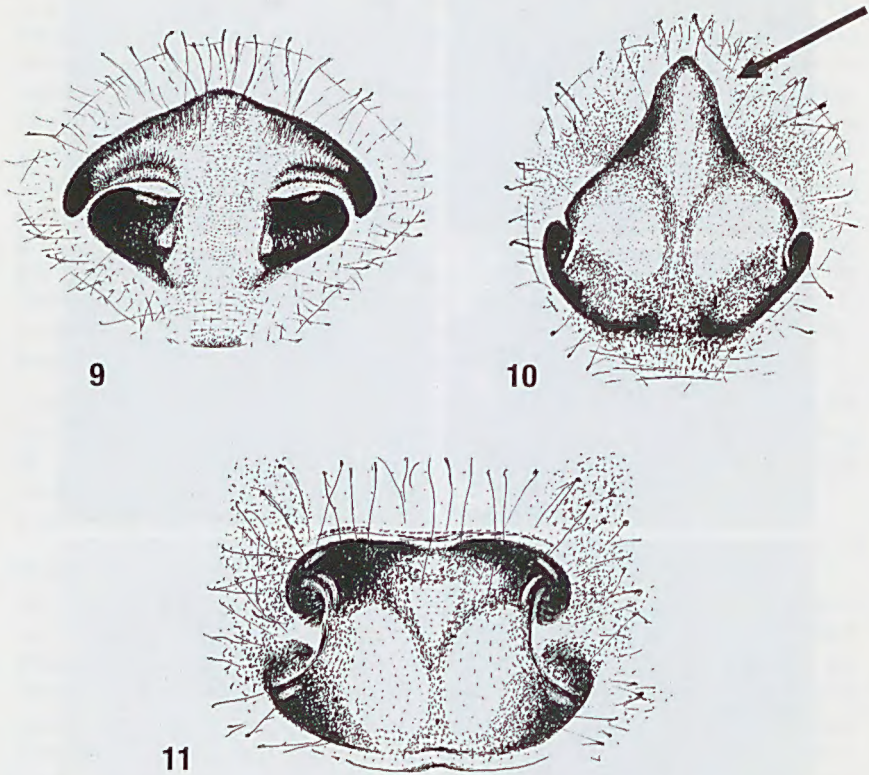
#### *Female genitalia*

The external genitalia of females of the three species are easy to differentiate (Figs 9-11). *O. molarius* has a median septum with a broad longitudinal process, while *O. amoenus* has a median septum with a narrow and attenuate longitudinal process. *O. gracilipes* has a broad median septum with no processes.





**Figs 1-8.** Photographs of female (left) and male (right) *Oxyopes* spp. commonly found in cotton in the Lower Namoi Valley, NSW. (1-2): *O. molarius* (pale morph); (3-4): *O. molarius* (dark morph); (5-6): *O. amoenus*; (7-8): *O. gracilipes*. Note the bands on the legs of *O. amoenus* (Figs 5-6), and the longitudinal stripe on the femur of *O. gracilipes* (Figs 7-8). The dark morph in *O. molarius* can be produced by the loss of the light hair covering from the pale morph.

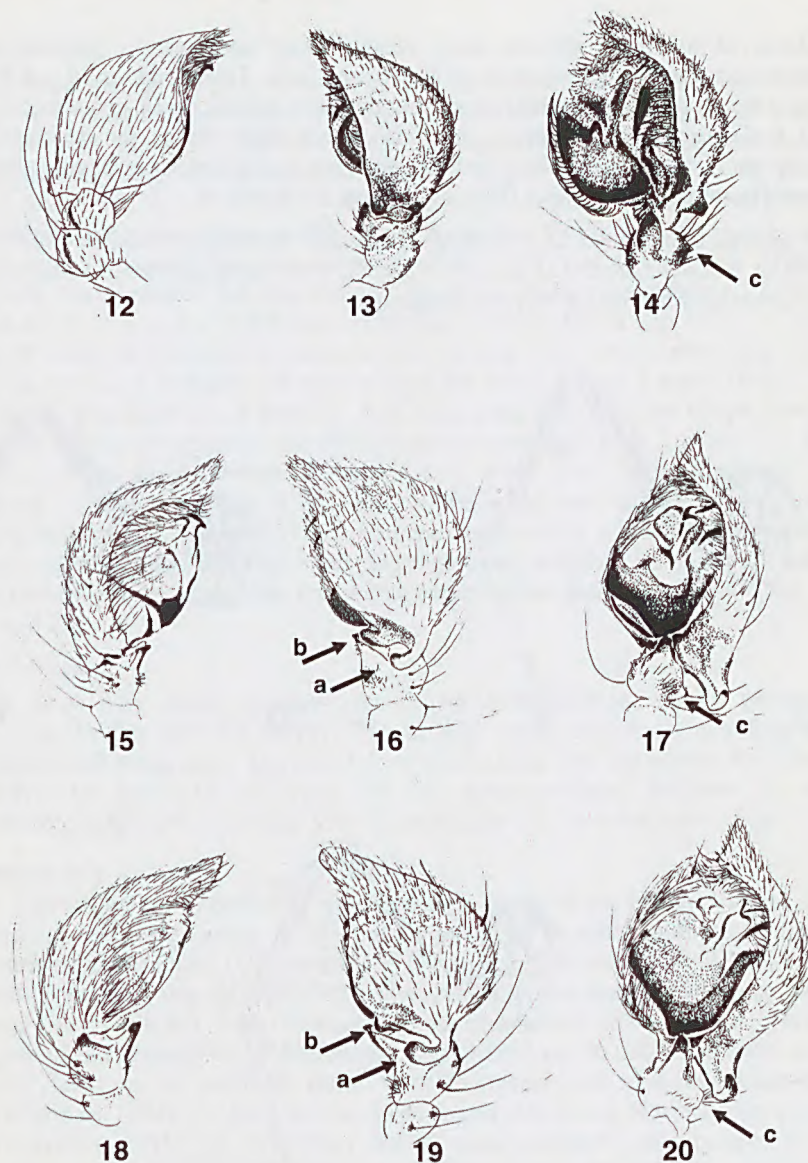


**Figs 9-11.** Epigyna of *O. molarius* (9), *O. amoenus* (10) and *O. gracilipes* (11), showing differences in the median septum, which extends anteriorly in *O. amoenus* (arrowed).

#### *Male genitalia*

Distinguishing between the palps of *O. gracilipes* and that of the other two species is relatively easy; *O. gracilipes* has a small, triangular cymbial apophysis (Fig. 13) instead of the large, distinctively hooked cymbial apophysis of *O. amoenus* and *O. molarius* (Figs 16 and 19 respectively, arrow a). However, distinguishing between males of *O. molarius* and *O. amoenus* is difficult. The only differences we found between the palps of these two species were the shape of the hook (Figs 16 and 19, arrow a; the hook is longer and more curved in *O. molarius*) and the shape of a second cymbial apophysis, which is a small mound in *O. molarius* and bears a thickened proximal border resembling a hook in *O. amoenus* (Figs 16 and 19, arrow b).

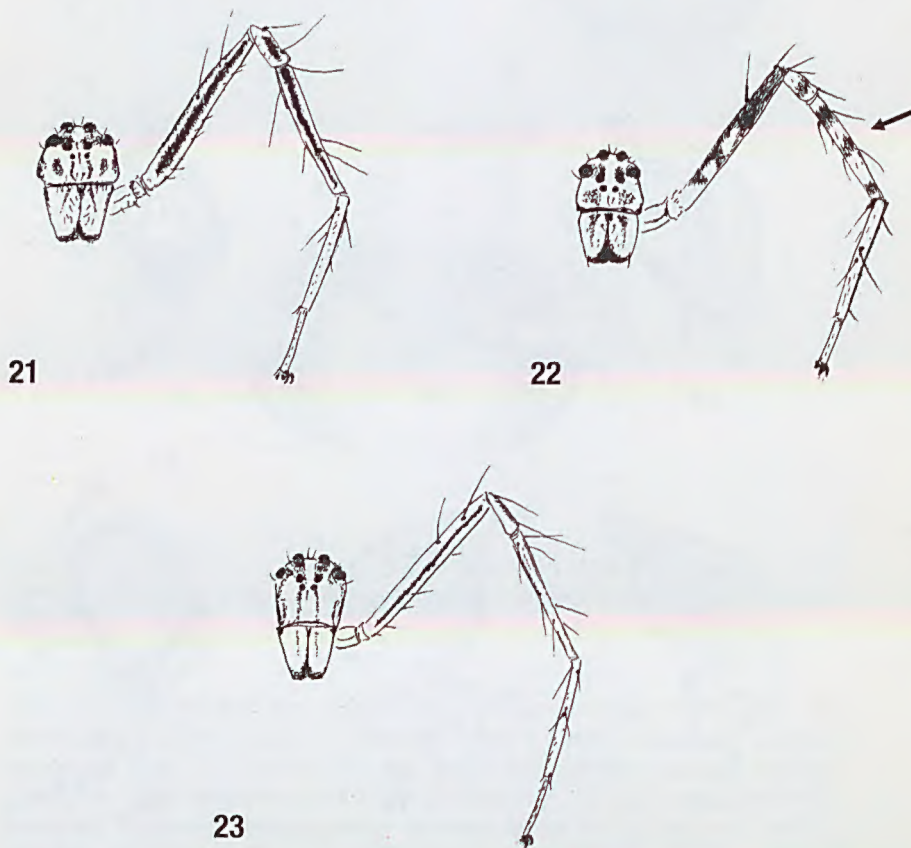




**Figs 12-20.** Male palps of *O. gracilipes* (12: lateral; 13: dorsal; 14: ventral view), *O. amoenus* (15: lateral; 16: dorsal; 17: ventral view) and *O. molarius* (18: lateral; 19: dorsal; 20: ventral view), showing the hooked cymbial apophysis (arrow a) in *O. molarius* and *O. amoenus*. In *O. molarius* the hook is longer and more curved, while in *O. amoenus* a second cymbial apophysis (arrow b) shows a thickened proximal boarder resembling a hook. Arrow c = retrolateral tibial apophysis.

Males of all three species have ventral tibial apophyses (opposite the thickened border: arrow b in Figs 16 and 19). Townsend *et al.* (2001) identified a retrolateral tibial apophysis that was present on *O. gracilipes* and *O. molarius* but missing on *O. amoenus*. In our observations, the structure is clear on *O. gracilipes*, while both *O. molarius* and *O. amoenus* have a slight retrolateral tibial apophysis (Figs 14, 17 and 20, arrow c).

In general appearance, *O. gracilipes* is sexually dimorphic while *O. molarius* and *O. amoenus* are not (Figs 2, 4, 6 and 8). The cephalothorax of some male *O. gracilipes* had an underlying orange hue.



**Figs 21-23.** Markings on leg I of *O. molarius* (21), *O. amoenus* (22) and *O. gracilipes* (23). *O. gracilipes* has a single, sharp black stripe; *O. molarius* has either no stripe or one or two broader and more diffuse stripes; *O. amoenus* has no longitudinal stripes but has transverse bands around the patellae and tibiae (arrowed).



### Legs

All three species are very variable in their abdominal pattern due to abrasion of the coloured scales; hence it is very difficult to distinguish between them in the field, especially between juveniles. In general, *O. gracilipes* has more slender legs and is slightly smaller (body length, male: mean = 4.5 mm, std.dev. = 0.3, n = 25; female: mean = 5.9 mm, std.dev. = 0.8, n = 25) than either *O. molarius* (body length, male: mean = 6.5 mm, std.dev. = 0.9, n = 24; female: mean = 8.3 mm, std.dev. = 1.4, n = 31) or *O. amoenus* (body length, male: mean = 6.4 mm, std.dev. = 1.2, n = 26; female: mean = 7.8 mm, std.dev. = 1.3, n = 26) but this difference is often difficult to observe. The most useful distinguishing characteristic of both adults and juveniles of the three species is probably the markings on the femur of legs I and II (Figs 21-23). *O. gracilipes* has a distinct, thin, dark longitudinal stripe on prolateral femur I (like the seam on old-fashioned silk stockings: Figs 7, 8 and 23). *O. molarius* has more variable leg markings; in some there are no markings on femur I, while in others it has one or two broad and diffuse longitudinal stripes (Figs 1, 2, 3, 4 and 21). *O. amoenus* is generally a much darker spider than the other two; although it has no longitudinal stripe on its femur I it may have dark patches and it has transverse bands on the patella and tibia (Figs 5, 6 and 22).

### Distribution

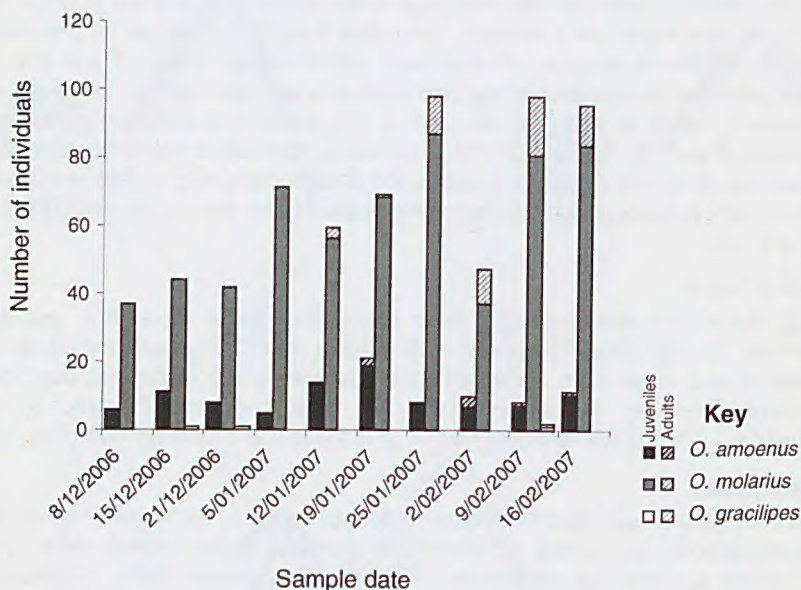
All three lynx spider species were found throughout the cotton growing season. In the 2006/07 survey, 766 spiders were collected (including 62 adults) and these were identified to species using the characters described above. Of these, *O. molarius* was the most common, followed by *O. amoenus*. During this drought year *O. gracilipes* was relatively rare (Fig. 24).

### Discussion

We identified three species of lynx spiders in cotton in the Namoi Valley. All three species are found in all cotton growing regions southwards from southern Queensland (Grimshaw 1991, Vink and Sirvid 2000, Whitehouse and Grimshaw, unpublished data). *Oxyopes molarius* and *O. amoenus* have also been collected from Townsville and Emerald in northern and central Queensland respectively (Whitehouse and Grimshaw, unpublished data) and both occur as far north as Cape York Peninsula and in South Australia (Grimshaw 1991). *O. amoenus* has been found also in the Northern Territory (Grimshaw 1991). *O. gracilipes* has a more southerly distribution, with specimens found in SE Queensland and coastal regions of NSW, Victoria, South Australia and SW Western Australia (Grimshaw 1991). Thus, although this study focuses on the Namoi Valley, the species described are relevant to most cotton growing regions in Australia.

Although spiders are one of the largest and most common invertebrate groups in cotton, they are often ignored as agents in pest management. This is largely because most work to date has focused on insects rather than spiders.

Consequently, the insect fauna in crops is well documented and much is known about insect responses to crop conditions. This information has generated models on insect economic thresholds and the effect of beneficial insects on these thresholds (e.g. 'the predator to pest ratio': Mensah 2002, Deutscher *et al.* 2005). Because spiders are quite distinct from insects, models extrapolated from insect work may be not suitable for spiders. In addition, spider species in cotton have not been well documented, making it difficult for crop scouts to identify spiders beyond family level. Improving spider identification will enable information specific to key spider species to be incorporated into the management of pest species.



**Fig. 24.** Number of lynx spiders caught in beatsheets in cotton during the 2006/07 season. In this drought year, *O. molarius* was the most common, followed by *O. amoenus*; *O. gracilipes* was rare.

As mirids and other secondary pests become more of a problem in cotton, it is important that key predators are accurately identified. Particular species of lynx spiders are known to attack mirids. For example, the striped lynx spider, *Oxyopes salticus* Hentz, is responsible for 15-18% of the daily mortality of the cotton fleahopper *Pseudatomoscelis seriatus* (Reuter) (Hemiptera: Miridae) in Texan cotton fields (Nyffeler *et al.* 1992) and 31% of all striped lynx spiders in cotton had consumed immature fleahoppers (Breene *et al.*



1989). In Australia, Bishop and Blood (1981) identified *O. gracilipes* (as *Oxyopes mundulus* L. Koch) as an important predator of *Helicoverpa* spp larvae in Australian cotton crops. In our own work we found that female *O. molaris* were particularly good at attacking adult mirids, while *O. gracilipes* was not as effective (Whitehouse and Barnes, unpublished data). To make use of this information and develop it further, it is important to be able to easily distinguish between these two very similar species.

### Acknowledgements

We thank Judy Nobile (CSIRO Entomology) for the illustrations and photographs and for maintaining the spiders in the laboratory, and Rob Raven (Queensland Museum) for comments on the manuscript and access to collections. This research was funded by the Cotton Research and Development Corporation (project number: 3.2.19 AC), and the Cotton Catchment Communities Cooperative Research Centre (project number: 1.01.01).

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## A REVIEW OF *CALLISTOMYIA* BEZZI AND RELATED GENERA (DIPTERA: TEPHRITIDAE: TRYPETINAE)

D.L. HANCOCK

PO Box 2464, Cairns, Qld 4870

### Abstract

The new tribe Callistomyiini is proposed for the Indo-Australian genera *Callistomyia* Bezzi and *Alincocallistomyia* Hardy, plus the African genus *Sosiopsila* Bezzi. This tribe might also include the Neotropical genera *Alujamyia* Norrbom, *Molynocoelia* Giglio-Tos and *Pseudophorellia* Lima. The African *Sosiopsila trisetosa* Bezzi, stat. rev., is removed from synonymy with *S. metadacus* (Speiser). The identity of the Indian *Dacus klugii* Wiedemann is discussed, with the species removed from *Callistomyia* and placed in the new combination *Euphranta klugii* (Wiedemann), close to *E. apicalis* Hendel. A key to the three genera and eight species known from the Old World is included.

### Introduction

The Indo-Australian genera *Callistomyia* Bezzi and *Alincocallistomyia* Hardy have had a chequered taxonomic history. Currently included in the otherwise Neotropical tribe Hexachaetini (e.g. Korneyev 1999, Hancock and Drew 2003, Agarwal and Sueyoshi 2005), they were previously placed in the tribes Acanthonevrini (Hardy 1986, 1988) or Trypetini (Hancock and Drew 1994, Permkam and Hancock 1995, Wang 1998). However, a recent study by Norrbom (2006) suggests that they represent a distinct clade closely related to the Neotropical genera *Alujamyia* Norrbom, *Molynocoelia* Giglio-Tos and *Pseudophorellia* Lima, with *Hexachaeta* Loew forming a separate clade with *Anastrepha* Schiner and *Toxotrypana* Gerstaecker (the latter three genera all placed in tribe Toxotrypanini). Norrbom (2006) suggested that they might also be related to tribe Adramini; however, all lack long, fine hairs on the anatergite, a key defining character for that tribe and (as indicated by Norrbom 2006) a sister-group relationship with the Toxotrypanini seems more certain.

Tribal placement of the African genus *Sosiopsila* Bezzi has been equally uncertain. Hancock (1986) transferred it from the Adramini to tribe Phytalmiini but the yellow dorsal stripe on the anepisternum and the lack of preapical setae on the aculeus suggest that this was incorrect. It was returned tentatively to [or near] the Adramini by Korneyev (1999) and Hancock (2003). However, it also lacks long, fine hairs on the anatergite and its inclusion within the Adramini remained doubtful. The shape and structure of the spermathecae, the male fifth sternite and the aedeagus closely resemble those of *Callistomyia* (see Munro 1984, Hardy 1973, 1974, Permkam and Hancock 1995), the unusually shaped, apically trilobed aculeus is similar to that seen in *Pseudophorellia* (see Hancock 1986, Norrbom 2006), while the shape of the epandrium and proctiger resemble that of *Molynocoelia* (see Munro 1984, Norrbom 2006). *Sosiopsila* shares with *Alincocallistomyia* and *Callistomyia* the pubescent arista, ocellar setae vestigial or absent, vein  $R_{4+5}$

extensively setose and an apically pointed aculeus without preapical setae. *Sosiopsila* has only one pair of scutellar setae (2-3 pairs in the other genera) but this appears to be the medial pair, with the basal and apical pairs lost. *Sosiopsila* is here tentatively included with the latter two genera within the new tribe Callistomyiini, which might also include the *Molynocoelia* group of genera (see Norrbom 2006).

#### Subfamily TRYPETINAE

#### Tribe CALLISTOMYIINI nov.

Type genus *Callistomyia* Bezzi.

This tribe is proposed to accommodate a group of apparently related genera that lack defining characters of other tribes currently included in the subfamily Trypetinae (see Korneyev 1999, Norrbom 2006). Two Indo-Australian genera (*Alincocallistomyia* Hardy, *Callistomyia* Bezzi) and one African genus (*Sosiopsila* Bezzi) are included. Three Neotropical genera (*Alujamyia* Norrbom, *Molynocoelia* Giglio-Tos and *Pseudophorellia* Lima) might also belong here.

**Diagnosis.** Head generally with 1-2 pairs of orbital setae and 2-3 pairs of frontal setae; ocellars weak or absent; all setae dark and acuminate; arista usually pubescent; occiput swollen ventrally. Scutum generally fulvous to reddish, with or without dark spots or vittae; anepisternum usually with a yellow dorsal band from postpronotal lobe to wing base; anatergite without long, fine hairs; postpronotal, presutural, dorsocentral and prescutellar acrostichal setae present or absent; dorsocentrals, when present, posterior in position, close to line of postalars; intrapostalars lacking; 1-3 pairs of scutellar setae. Legs often with a second, smaller spine at apex of mid tibia and with or without two rows of ventral spinules on mid and hind femora. Wing usually banded but pattern sometimes modified or reduced; veins  $R_1$  and  $R_{4+5}$  extensively setose; no distinct costal seta at base of pterostigma; pterostigma usually narrow and apically acute; vein M not distinctly curved upwards at apex; cell *bcu* weakly or strongly acuminate but apical extension not basally constricted. Abdominal tergites not fused, often with dark spots or bands but without shiny black bullae; aculeus apically acute, sometimes trilobed with the preapical lobes also acute, and without preapical setae; eversible membrane with ventral spicules much more extensive than dorsal spicules (Norrbom 2006: unchecked for *Sosiopsila*); 2-3 spermathecae, usually round or mushroom-shaped.

#### The identity of '*Callistomyia*' *klugii*

*Dacus klugii* Wiedemann was described from 'India orient[alis]' by Wiedemann (1824) ['orientalis' signifying India proper rather than the West Indies]. Bezzi (1913) tentatively suggested it might belong in *Callistomyia* and that was followed, without further comment, by Hardy (1951) and all subsequent authors. No additional specimens have been referred to it since its



original description and neither Senior-White (1924) nor Kapoor (1970) mentioned it. However, the name has been recognised as valid in several recent catalogues (Hardy 1977, Kapoor 1993, Norrbom *et al.* 1999, Agarwal and Sueyoshi 2005) and in at least three systematic keys (Hardy 1951, 1974, Kapoor 1993).

The type (in the Zoological Museum, University of Copenhagen) is possibly from the Calcutta district of West Bengal, where Dagobert Daldorf (the likely collector) was based between 1798 and his death in 1802 (Courtice 2006). Unfortunately, I have not been able to obtain any additional information on the type but Wiedemann's (1830) description suggests it belongs in genus *Euphranta* Loew. Note that the basal, transverse wing band enclosing crossvein BM-Cu is [dark] brown, not yellowish as in *Callistomyia*, and that the hyaline distal areas are 'whitish'. It appears closest to, and is possibly synonymous with, *E. apicalis* Hendel, seemingly differing only in the apparent absence of dark brown vittae on the scutum and a smaller hyaline apical spot on the wing (confined to cell  $r_{4+5}$ ).

A relationship with *Euphranta apicalis*, a species widespread in southeast Asia but not yet recorded from India, is suggested by size and overall body colour, apparent similarities in wing pattern and the presence of a pair of blackish facial spots (Wiedemann 1830, Hendel 1915). However, the nearest recorded locality for *E. apicalis* is the Moulmein district of southern Burma (Hering 1938, Wang 1998) and, in the absence of additional Indian material and without further information on the type, formal synonymy would be premature. Therefore, *Euphranta klugii* (Wiedemann, 1824), comb. n. and *Euphranta apicalis* Hendel, 1915 are regarded here as separate species placed in the *apicalis* group of Hancock and Drew (2004).

It should be noted that, prior to Daldorf's return to India in 1798, he also collected in Sumatra (Courtice 2006), where *E. apicalis* is known to occur (Hancock and Drew 2004); however, given the original type locality of 'India [of the East]' (Wiedemann 1824), the Calcutta district is a more likely provenance. Wiedemann (1830) subsequently misstated the type locality as 'Ostindien', leading some authors (*e.g.* Hardy 1951) to incorrectly interpret the type locality as 'East Indies' [Indonesia].

### Key to Old World genera and species of tribe Callistomyiini

- 1 One pair of scutellar setae; postpronotal and dorsocentral setae absent; mid and hind femora without rows of black ventral spinules; wing without a transverse band across R-M crossvein; cell *bcu* weakly acute apically (Africa) ..... *Sosiopsila* Bezzi ... 2
- Two or three pairs of scutellar setae; postpronotal and dorsocentral setae present; mid and hind femora with rows of black ventral spinules; wing with a transverse band across R-M crossvein; cell *bcu* strongly acute apically (Indo-Australia) ..... 4

- 2 Postnotum fulvous, at most with a slight medial darkening; apical wing spot extending narrowly (for about 1/3 length) below vein  $R_{4+5}$  (South Africa) ..... *S. rotunda* Munro
- Postnotum with a distinct medial black or brown patch; apical wing spot extending broadly (for 1/2-2/3 length) below vein  $R_{4+5}$  ..... 3
- 3 Costal band in cell  $r_1$  narrow but distinct, wider than costal vein (Nigeria to Ethiopia and ?Kenya) ..... *S. metadacus* (Speiser)
- Costal band in cell  $r_1$  absent or vestigial, no wider than costal vein (Malawi to South Africa) ..... *S. trisetosa* Bezzi
- 4 Three pairs of scutellar setae; prescutellar setae present; no distinct propleural seta (Borneo) ..... *Alincocallistomyia imitator* Hardy
- Two pairs of scutellar setae; prescutellar setae absent; a distinct propleural seta present ..... *Callistomyia* Bezzi ... 5
- 5 Wing with large apical spot broadly connected in posterior half of cell dm with transverse band across R-M crossvein; abdomen without black transverse bands on terga III-V [present or absent on tergite II] (northern Australia, southern Papua New Guinea) ..... *C. horni* Hendel
- Wing with large apical spot broadly isolated or at most narrowly connected along vein  $Cu_1$  with transverse band across R-M crossvein; abdomen usually with black transverse bands on terga II-V ..... 6
- 6 Wing with large apical spot narrowly connected with transverse band along vein  $Cu_1$  (Philippines) ..... *C. icarus* (Osten Sacken)
- Wing with large apical spot broadly separated from transverse band ..... 7
- 7 Wing with large apical spot diffusely connected with costal band along apical margin of cell  $r_{2+3}$  (India and China to western Indonesia) ..... *C. pavonina* Bezzi
- Wing with large apical spot not connected with costal band along apical margin of cell  $r_{2+3}$  (eastern Indonesia, northern Papua New Guinea) ..... *C. flavilabris* Hering

## Systematics

### Genus *ALINCOCALLISTOMYIA* Hardy

*Alincocallistomyia* Hardy, 1986: 28. Type species *A. imitator* Hardy.

One species, from the island of Borneo. Larval hosts unknown.

### *Alincocallistomyia imitator* Hardy

*Alincocallistomyia imitator* Hardy, 1986: 29. (near Tawau, Sabah, Malaysia).

*Distribution.* Known only from Sabah, east Malaysia.



Genus *CALLISTOMYIA* Bezzi

*Callistomyia* Bezzi, 1913: 124. Type species *C. pavonina* Bezzi.

Four allopatric Indo-Australian species. Larval hosts Rutaceae (subfamily Aurantiodeae). For a habitus illustration of the type species, see Hancock and Drew (1994). The Australian *C. horni* has a distinctive wing pattern but the other three species (*C. flavilabris*, *C. icarus* and *C. pavonina*) are only weakly separable.

*Callistomyia flavilabris* Hering

*Callistomyia flavilabris* Hering, 1953: 513. (Misool, Indonesia).

*Distribution.* Eastern Indonesia (Maluku Province: Misool) and northern Papua New Guinea (Madang Province).

*Host plant.* Berries of *Wenzelia dolichophylla* (Rutaceae) (Hancock and Drew 2003).

*Callistomyia horni* Hendel

*Callistomyia horni* Hendel, 1928: 361. (Palmerston [Darwin], Northern Territory).

*Distribution.* Southern Papua New Guinea (Central Province) and Australia (northern areas of Western Australia, Northern Territory and Queensland).

*Host plants.* Berries of *Clausena*, *Glycosmis* and *Micromelum* species (Rutaceae) (Permkam and Hancock 1995).

*Callistomyia icarus* (Osten Sacken)

*Dacus icarus* Osten Sacken, 1882: 224. (Philippines).

*Callistomyia icarus*: Hardy, 1974: 160. (Luzon).

*Distribution.* Philippines (Luzon).

*Host plants.* None recorded.

*Callistomyia pavonina* Bezzi

*Callistomyia pavonina* Bezzi, 1913: 125. (NE India).

*Callistomyia flavilabris*: Hardy, 1973: 177-178. (Malaysia). Misidentification.

In specimens previously referred to *C. pavonina*, the dark facial spot is variable in intensity and is often absent. Malaysian specimens of '*C. flavilabris*' recorded by Hardy (1973) were regarded as examples of *C. pavonina* with the facial spot absent by Hancock and Drew (1994).

*Distribution.* India, Sri Lanka, China, Taiwan, Thailand, Laos, Vietnam, west Malaysia and western Indonesia (Sumatra, Java).

*Host plants.* Berries of *Clausena* and *Glycosmis* species (Rutaceae) (Hancock and Drew 1994).

Genus *SOSIOPSILA* Bezzi

*Sosiopsila* Bezzi, 1920: 214. Type species *S. trisetosa* Bezzi.

Three poorly differentiated (and apparently allopatric) African species that are probably little more than subspecies. Larval hosts unknown. Munro (1984) suggested that larvae were probably stem borers, but that is unlikely to be the case. For a habitus illustration of the type species, see Hancock (1986, as *metadacus*).

*Sosiopsila metadacus* (Speiser)

*Polystodes metadacus* Speiser, 1915: 99. (Zela, Mandarra Mts, Cameroon).

*Sosiopsila metadacus*: Hancock, 1986: 304. (Cameroon).

*Distribution*. Known from northern Nigeria, Cameroon and Ethiopia (material in The Natural History Museum, London) and possibly western Kenya (Copeland *et al.* 2005, as *Sosiopsila* sp. cf. *metadacus*).

*Sosiopsila rotunda* Munro

*Sosiopsila rotunda* Munro, 1933: 26. (Rosslyn, South Africa).

*Distribution*. Known from northern and eastern South Africa (North-West Province: Rosslyn and Rustenburg; KwaZulu-Natal: Durban).

*Sosiopsila trisetosa* Bezzi; **stat. rev.**

*Sosiopsila trisetosa* Bezzi, 1920: 215. (East of Mt Mlanje, Mozambique).

*Sosiopsila metadacus*: Hancock, 1986: 303-304. (Zimbabwe). Misidentification.

This species was placed as a synonym of *S. metadacus* by Hancock (1986). However, examination of further material (in The Natural History Museum, London) suggests that the variation observed (particularly the presence or absence of a distinct costal band) is at least partly geographical.

*Distribution*. Known from southern Malawi, Mozambique, Zimbabwe and northeastern South Africa (Mpumalanga Province: Nelspruit).

**Acknowledgement**

I thank Nigel Wyatt (The Natural History Museum, London) for access to material in his care.

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**A NEW SPECIES OF THE SUBGENUS *POLYRHACHIS*  
(*CYRTOMYRMA*) FOREL (HYMENOPTERA: FORMICIDAE:  
FORMICINAE) FROM BORNEO**

RUDOLF J. KOHOUT

*Biodiversity Program, Queensland Museum, PO Box 3300, South Brisbane, Qld 4101*

*(Email: rudolfkohout@qm.qld.gov.au)*

**Abstract**

*Polyrhachis acuminata*, a new species of the subgenus *Cyrtomyrma* Forel, is described and illustrated from Sabah, Malaysia.

**Introduction**

During a recent, one day visit to Poring Hot Springs in Kinabalu Park, Sabah, Malaysia, I collected a few *Polyrhachis* Fr. Smith specimens, including two that I regarded at the time to belong to a species recently described as *Polyrhachis* (*Cyrtomyrma*) *danum* Kohout (Kohout 2006). These specimens featured several characteristics of that species, including distinctly reddish-brown appendages and a similar mesosomal outline. However, following my return to Brisbane, closer examination of the specimens revealed them to be an undescribed species. This discovery was made too late for the species to be included in my recent revision of the Bornean fauna of subgenus *Cyrtomyrma* Forel (Kohout 2006) and consequently it is described below.

Abbreviations of institutions (with names of curators) are: ITBC = Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, East Malaysia (Dr Maryati Mohamed); QMBA = Queensland Museum, Brisbane, Australia (Dr Chris J. Burwell).

**Methods**

Photographs of the holotype were taken by Geoff Thompson (QMBA) with a Leica DFC500 Camera and Leica MZ16A stereomicroscope, using Leica Application Suite Software. The images were then processed using Auto-Montage (Syncroscopy, Division of Synoptics Ltd, USA) and Adobe CS2 (Adobe Systems Inc, USA) software.

Standard measurements and indices are as follows: TL = Total length (the necessarily composite measurement of the outstretched length of the entire ant measured in profile); HL = Head length (the maximum measurable length of the head in perfect full face view, measured from the anterior-most point of the clypeal border or teeth, to the posterior-most point of the occipital margin); HW = Head width (width of the head in perfect full face view, measured immediately in front of the eyes); CI = Cephalic index ( $HW \times 100/HL$ ); SL = Scape length (length of the antennal scape, excluding the condyle); SI = Scape index ( $SL \times 100/HW$ ); PW = Pronotal width (greatest width of the pronotal dorsum); MTL = Metathoracic tibial length (maximum measurable length of the tibia of the hind leg). All measurements were taken

using a Zeiss SR stereomicroscope with an eyepiece graticule calibrated against a stage micrometer and are expressed in millimetres (mm).

***Polyrhachis acuminata* sp. n.**

(Figs 1-2)

*Types.* *Holotype worker*, EAST MALAYSIA (SABAH): Kinabalu Park, Poring Hot Springs, 06°02'N, 116°43'E, 27.vi.2006, R.J. & E. Kohout acc. 06.5. *Paratype*: 1 worker, same data as holotype. Holotype in ITBC; paratype in QMBA.

*Description.* Worker. Dimensions (holotype cited first): TL c. 6.55, 6.75; HL 1.59, 1.62; HW 1.50, 1.53; CI 94, 94; SL 1.96, 2.03; SI 131, 133; PW 1.18, 1.22; MTL 2.34, 2.37 (2 measured). Mandibles with 5 teeth, apical tooth longest, other teeth subequal in length. Anterior clypeal margin obtusely truncate with shallow median notch. Clypeus in profile convex with shallow depression behind anterior margin and moderately impressed basal margin. Frontal triangle indistinct. Frontal carinae sinuate with weakly raised margins; central area shallowly concave with shallowly impressed frontal furrow. Sides of head in front of eyes converging towards mandibular bases in weakly convex line; behind eyes sides rounding into convex occipital margin. Eyes moderately convex, in full face view only marginally breaking lateral cephalic outline. Ocelli lacking. Pronotum in dorsal view with humeri widely rounded, with greatest pronotal width just before mid-length of segment. Mesosoma in profile moderately convex, with promesonotal suture distinctly impressed; metanotal groove lacking dorsally, weakly indicated laterally. Propodeal dorsum with indication of rudimentary propodeal spines; rounding into relatively short, oblique declivity. Petiole with dorsal spines reduced to short, blunt, wide-based teeth; lateral spines up to four times as long as their basal width, slender and acute. Subpetiolar process relatively long, angular anteriorly, narrowly rounded posteriorly. Anterior face of first gastral segment in lateral view lower than full height of petiole, very weakly concave at base, narrowly rounding onto dorsum of segment.

Mandibles finely longitudinally striate with numerous piliferous pits; sculpture becoming rather smooth and polished towards bases. Head, mesosoma, petiole and gaster very finely shagreened, rather polished with numerous shallow punctures; sculpture becoming somewhat finely wrinkled on meso- and metapleurae. Petiole very finely transversely wrinkled, with sculpture more intensely reticulate-rugose at base.

Mandibles with numerous semierect hairs at masticatory borders. Anterior clypeal margin with several moderately long, anteriorly directed setae and a few short setae lining margin laterally. Two pairs of erect hairs arising near anterior margin and one pair along frontal carinae. Rather long, erect hairs on anterior face of fore coxae; distinctly shorter hairs on posterior face and on ventral surfaces of trochanters. Gaster with medium length, erect hairs lining posterior margins of apical segments, hairs on gastral venter more abundant.



Black, with mandibular masticatory borders, condylae and extreme tips of apical funicular segments reddish-brown. Legs, including trochanters, distinctly red or reddish-brown with proximal ends of tibiae, coxae and tarsi virtually black.

Sexuals and immature stages unknown.

*Etymology.* From the Latin *acuminatus*, meaning pointed, in reference to the long, sharply pointed lateral petiolar spines.



**Figs 1-2.** *Polyrhachis acuminata* sp. n., holotype worker: (1) dorsal view; (2) lateral view.

*Remarks.* *Polyrhachis acuminata* is very similar to *P. danum* and *P. lepida* Kohout, both also known from Sabah. All three species are distinctly bicoloured with the head, mesosoma, petiole and gaster black and most of the legs bright red or reddish-brown. They have a rather similar lateral mesosomal outline, except that the propodeal declivity is virtually vertical in *P. danum* and *P. lepida*, while it is oblique in *P. acuminata*. *Polyrhachis acuminata* is also distinguished by its rudimentary propodeal spines that are completely absent in *P. danum* or indicated only as barely visible tubercles in some *P. lepida* specimens. The mesosomal sculpturation is uniformly finely shagreened in *P. danum*, while the sides of the mesosoma are wrinkled in *P. acuminata* and distinctly reticulate-rugose in *P. lepida*. However, the main character that distinguishes the three species is the configuration of petiolar spines. In *P. danum*, all the petiolar spines are reduced to minute denticles,

while in *P. acuminata* and *P. lepida* the dorsal pair are wide-based and tooth-like and the lateral spines are long and slender. In *P. acuminata* the lateral spines are up to four times as long as their basal widths, while they are only twice as long or shorter in *P. lepida*. The species also differ in their relative sizes, with *P. lepida* the smallest and *P. danum* the largest (HL 1.40-1.50 in *P. lepida*, 1.59-1.62 in *P. acuminata* and 1.65-1.87 in *P. danum*).

### Key to Bornean *P. (Cyrto-myrrma)* species

*Polyrhachis acuminata* is the latest addition to the list of Bornean *Cyrto-myrrma* species and can be identified using the following modification to the key to Bornean species in Kohout (2006). Figure numbers refer to illustrations in the original article. *Polyrhachis rastellata* (Latreille), erroneously recorded from Borneo in the past (see Kohout 2006 for details), is included in the key for completeness.

- 6 Larger species (HL >1.65); petiole with sides more-or-less parallel, spines reduced to minute denticles (Fig. 6F) ..... *danum* Kohout
- Smaller species (HL <1.65); petiole with sides diverging, spines acute (Fig. 7B, D) ..... 7
- 7 Pronotal shoulders broadly rounded; lateral petiolar spines up to four times as long as their basal width ..... *acuminata* sp. n.
- Pronotal shoulders narrowly rounded or subangular (Fig. 7A); lateral petiolar spines at most twice as long as their basal width ..... 8
- 8 Propodeal declivity very steep, virtually vertical (Fig. 7A); lateral petiolar spines distinctly longer than dorsal pair (Fig. 7B); legs dark reddish-brown ..... *lepida* Kohout
- Propodeal declivity oblique (Fig. 7C); petiolar spines subequal or lateral pair shorter than dorsal pair (Fig. 7D); legs mostly orange or light reddish-brown ..... *rastellata* (Latreille)

### Acknowledgements

I am very grateful to Prof. Datin Dr Maryati Mohamed (Director of the Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah) for continued logistic and financial support of my work on the taxonomy of Bornean *Polyrhachis*. My gratitude goes also to Geoff Thompson (Queensland Museum) for producing the digital images and Dr Chris Burwell (Queensland Museum) for reading and commenting on a draft of the manuscript.

### Reference

KOHOUT, R.J. 2006. Review of *Polyrhachis* (*Cyrto-myrrma*) Forel (Hymenoptera: Formicidae: Formicinae) of Australia, Borneo, New Guinea and the Solomon Islands with descriptions of new species. *Memoirs of the Queensland Museum* 52(1): 87-146.



## THE IDENTITY OF *TERELLIA IMMACULATA* MACQUART (DIPTERA: TEPHRITIDAE: TEPHRITINAE)

D.L. HANCOCK

PO Box 2464, Cairns, Qld 4870

### Abstract

*Terellia immaculata* Macquart, 1855 is placed as a new synonym of the Palearctic *Terellia longicauda* (Meigen, 1838). Its stated type locality of Marquesas Islands, French Polynesia, is regarded as an error, possibly for Marquise in NW France.

### Introduction

The fruit fly species *Terellia immaculata* Macquart has remained unrecognised since its original description (Macquart 1855). The type female is in the Oxford University Museum of Natural History (OUMNH) and is presumed to be of French Polynesian origin. Bezzi (1913) listed it from the Marquise Islands, while Hardy and Foote (1989) and Norrbom *et al.* (1999) both regarded it as an unplaced species of Tephritidae from French Polynesia (Marquesas Islands). However, the tephritine tribe Terelliini, to which *Terellia* Robineau-Desvoidy belongs, has not otherwise been reported from either the Australasian or Oceanian Regions.

Through the kindness of Adrian Pont and James Hogan (OUMNH), I have been able to examine photographs of the type female. Apart from a missing head, the type is in reasonably good condition and diagnostic characters are clearly visible. It is undoubtedly the same taxon as *Terellia longicauda* (Meigen), a widespread Palearctic species.

### *Terellia longicauda* (Meigen)

*Trypeta longicauda* Meigen, 1838: 356. (Bavaria, Germany).

*Trypeta acuticornis* Loew, 1846: 520. (? Wurttemberg, Germany).

*Terellia immaculata* Macquart, 1855: 145. (Iles Marquises [? Marquesas Is, French Polynesia] – error?). **Syn. n.**

*Terellia* (*Terellia*) *longicauda* (Meigen): Norrbom *et al.*, 1999: 222.

**Type data.** The type of *T. immaculata* carries the following labels: (1) [in handwriting of P.J.M. Macquart] – ‘*Terellia* R.D. / *immaculata* / ♀, Macq. n. sp.’; (2) [in handwriting of J.M.F. Bigot] – ‘*Trypeta immaculata*. ♀. / *Terellia*. id. Macq. / Ins. Marquis. Macq.’ [‘*rypeta*’ subsequently inserted after ‘*T*’ by J.E. Collin]; (3) [handwritten & printed] – ‘*T. immaculata* / EX COLL. BIGOT’; (4) [circular printed label with red border] – ‘Holo- / type’.

**Comments.** The characters of *T. immaculata* (particularly the scutal pattern, yellow scutellum, hyaline wing with a pale yellow stigma, sectional lengths of the medial vein, white-setose abdomen, long ov scape and aculeus shape) are consistent with those of *T. longicauda* as discussed and illustrated by White (1988) and Merz (1994). The stated type locality of ‘iles Marquises’ [Marquesas Is] is evidently erroneous and is possibly a misrepresentation of Marquise, a town near Boulogne in northwestern France.

*Host plant.* Larvae of *T. longicauda* feed in the flower heads of the thistle *Cirsium eriophorum* (L.) Scop. (Asteraceae: Cardueae) (White 1988, Merz 1994).

*Distribution.* Great Britain, central Europe and western Siberia to Spain, the Balkans and Iran (Norrbom *et al.* 1999).

## Discussion

With the removal of *Terellia immaculata* from the faunal list for the Marquesas Islands, only two other species of Tephritidae remain, the widespread *Dioxya sororcula* (Wiedemann) and the endemic *Trupanea simplex* Malloch (Hardy and Foote 1989). Both belong in tribe Tephritini in the flower-infesting subfamily Tephritinae. No fruit-infesting species are known from these remote Pacific islands (Purea *et al.* 1996).

## Acknowledgements

I thank Adrian Pont and James Hogan (UOMNH) for photographs of the type of *Terellia immaculata* and for help in interpreting the handwritten label data.

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**NOTES ON THE DISTRIBUTION AND BIOLOGY OF *TRAPEZITES GENEVIEVEAE* ATKINS, *SIGNETA TYMBOPHORA* (MEYRICK & LOWER) AND *HESPERILLA SARNIA* ATKINS (LEPIDOPTERA: HESPERIIDAE)**

ANDREW ATKINS

*PO Box 42, Eudlo, Qld 4554*

**Abstract**

Biological notes and distribution records are presented for three uncommon species of trapezitine skippers: *Trapezites genevieveae* Atkins, *Signeta tymbophora* (Meyrick & Lower) and *Hesperilla sarnia* Atkins.

**Introduction**

Between 2000 and 2007, a number of observations were made of three endemic trapezitine skippers in SE Queensland. Although the larval food plants of each species are local but fairly widespread within temperate and subtropical biomes in eastern Australia, the skippers are uncommon to rare with short flight seasons and are found only within limited areas. It appears that further, individually specific requirements, possibly climatic, altitude and microhabitat associations, are necessary to each species and thus are probable subjects of conservation value that emphasise the importance of the particular biomes that support them.

*Trapezites genevieveae* Atkins is restricted to dense old-growth montane rainforest from the Barrington Ranges in New South Wales to the Blackall Ranges in SE Queensland; *Signeta tymbophora* (Meyrick & Lower) is found very locally in coastal rainforest from near Narooma in New South Wales to upland temperate rainforest at Bunya Mts in SE Queensland; *Hesperilla sarnia* Atkins occurs from SE Queensland to the Cairns area of northern Queensland (Braby 2000). All three species have been found in mixed wet sclerophyll/upland rainforest at Mapleton in the Blackall Ranges (personal observations). Further searches for larvae and adults of these species beyond the northern extensions of the Sunshine Coast (southern Queensland) and also at Eungella Range (hinterland of Mackay, northern Queensland) so far have been unsuccessful.

**Observations**

*Trapezites genevieveae*

Adults are rarely seen and fly mostly near the tree canopy but larvae or 'larval cats' [distinctive oblique leaf cuts] are more easily found on the food plant, *Lomandra spicata* (Xanthorrhoeaceae), which grows on dark, damp slopes and near river banks deep within the forest (Atkins 1999). It is recorded from disjunct localities in SE Queensland but seems to be not uncommon on the border ranges at Springbrook, Green Mountain and Binna Burra. The food plant extends much further north, to the Atherton Tableland in northern Queensland. In recent surveys I have found *L. spicata* in both

upland and lowland rainforests in the hinterlands of the Sunshine Coast, as far north as 15 km NE of Kin Kin, and also in a small area (containing about 50 plants) on the slopes of Mt Dalrymple, Eungella Range west of Mackay (possibly a new locality record for the plant). There were no larval eats at this latter locality. Recent observations (2006-07) of larvae confirm the skipper's presence at Mt Mee, Conondale Ranges, Maleny, Montville and Mapleton, with possible larval eats at Peachester and in the forests north of Kin Kin. A further search of areas west of Miriam Vale might prove fruitful.

### *Signeta tymbophora*

In February 2007, I observed and collected a male flying in bright sunshine around and settling on 3 m high shrubs growing in a rainforest ravine in the Mapleton State Forest. Its food plants are various species of forest wire-grasses (Poaceae), *Gahnia* and *Carex* (Cyperaceae). A wire-grass was found nearby. *Lomandra spicata* and *Scleria sphacelata* also grow in this area. This is a new northern record for this small, dark skipper (probably about 20 km north of the inland locality at Bunya Mts).

### *Hesperilla sarnia*

As with *T. genevieveae*, observations of adults of this fast flying, dark brown skipper are rare; however, larval leaf-tube shelters and zigzag cuts to the leaf are more indicative of its presence. More than 15 localities, both lowland and upland, are known from the Sunshine Coast and hinterland (Atkins 2004). In 2006, three eggs were found on *Scleria sphacelata* (Cyperaceae), two on one plant at the same Mapleton forest locality as *S. tymbophora* and one on a plant at Forest Glen. The eggs were all located on the upper side of leaves close to the base of the plants. The eggs were 1 mm in diameter and had approximately 20 vertical ribs; all three appeared to be infertile. In February 2007, a slightly worn female was collected resting on grass growing within a new housing estate at Forest Glen. Compared with males, it was somewhat reluctant to fly and, when disturbed, flew rather sluggishly. This is probably the fifth record of a female of the southeastern form of this skipper.

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***LOPHODIPLOSIS TRIFIDA* GAGNÉ (DIPTERA: CECIDOMYIIDAE),  
A STEM-GALLING MIDGE WITH POTENTIAL AS A BIOLOGICAL  
CONTROL AGENT OF *MELALEUCA QUINQUENERVIA*  
(MYRTACEAE)**

M. PURCELL<sup>1</sup>, S. WINEWRITER<sup>2</sup> and B. BROWN<sup>1</sup>

<sup>1</sup>CSIRO Entomology, United States Department of Agriculture, Agricultural Research Service,  
Australian Biological Control Laboratory, 120 Meiers Road, Indooroopilly, Qld 4068  
(Email: matthew.purcell@csiro.au)

<sup>2</sup>United States Department of Agriculture, Agricultural Research Service, FDACS Florida  
Biocontrol Laboratory, PO Box 147100, Gainesville, Florida 32614-7100, USA

**Abstract**

The gall midge *Lophodiplosis trifida* Gagné was originally described as an inquiline of galls formed by three other *Lophodiplosis* Gagné species on *Melaleuca dealbata* and *M. quinquenervia*. However, field observations conducted throughout the native range of *M. quinquenervia*, coupled with replicated laboratory studies, have shown that *L. trifida* forms unique stem galls on *Melaleuca* species within the *M. leucadendron* complex. *Melaleuca quinquenervia* is an invasive weed in Florida, USA and *L. trifida* is a candidate biological control agent of that species.

**Introduction**

*Melaleuca quinquenervia* S. T. Blake is a federally and state listed invasive tree in southern Florida, USA (Turner *et al.* 1998). Since 1996, explorations for host-specific natural enemies have been conducted by the United States Department of Agriculture, Agriculture Research Service, Australian Biological Control Laboratory (USDA-ARS ABCL) throughout the range of *M. quinquenervia* in Australia.

A gall-forming cecidomyiid fly, then undescribed, was first collected in 1995 from *M. quinquenervia* growing in Queensland, by ABCL scientist J. K. Balciunas. It was described subsequently as *Lophodiplosis trifida* Gagné by Gagné *et al.* (1997), who reported it as an inquiline of three other *Lophodiplosis* Gagné galls – in leaf blister galls with *L. indentata* Gagné and *L. denticulata* Gagné on *M. quinquenervia*, and in bud rosette galls with *L. bidentata* Gagné on *M. dealbata* S. T. Blake (Gagné *et al.* 1997).

Since then, ABCL scientists have collected *L. trifida* from unique stem galls throughout the native range of *M. quinquenervia*. Specimens were sent to R. J. Gagné, who confirmed their identity. Voucher specimens are held at the Australian National Insect Collection, Canberra (ANIC) and the U.S. National Museum of Natural History, Smithsonian Institution, Washington, D.C.

**Observations**

*Lophodiplosis trifida* galls young shoots, predominantly during the autumn-winter period, when a flush of young foliage is produced by *M. quinquenervia* trees following flowering. The galls are variable in size and shape and can persist on the plant for long periods, resulting in deformed

branches. Close or overlapping utilisation of host tissue by *L. trifida*, *L. indentata*, *L. denticulata* and *L. bidentata* accounts for *L. trifida*'s original designation as an inquiline in other *Lophodiplosis* galls. In the absence of congeners, colonies of *L. trifida* have been established and sustained on young seedlings and plants of *M. quinquenervia* for many generations at ABCL. *Lophodiplosis trifida* readily galls the stems, curtailing shoot growth, that can sometimes lead to death of the plants.

## Discussion

The discovery that *L. trifida* is a stem galler of *M. quinquenervia*, rather than an inquiline, is significant, given that this particular gall possesses some of the traits considered desirable for biological control of weeds (Dennill 1988, Harris and Shorthouse 1996). The larvae of *L. trifida* live within the gall, the galled shoots occur at high densities, gall development spans the entire growth phase of the plant and gall development severs vascular tissue.

As part of a management plan for control of *M. quinquenervia*, three biological control agents have been introduced to Florida (USA) by scientists at the USDA-ARS Invasive Plant Research Laboratory (IPRL) since 1997, including a bud gall fly *Fergusonina turneri* Taylor (Goolsby *et al.* 2000, Davies *et al.* 2001). However, additional natural enemies are required that attack other plant stages. Elsewhere, gall formers have been used extensively in weed biological control programs (Julien and Griffiths 1998).

Initial screening of non-*Melaleuca* myrtaceous species by ABCL indicated that the host range of *L. trifida* is limited to *Melaleuca* species in the *M. leucadendron* complex. As a result, researchers of the IPRL and ABCL selected *L. trifida* to be imported and subjected to additional host range testing at the Florida Department of Agriculture and Consumer Services, Division of Plant Industry (FDACS DPI) quarantine facility in Gainesville, Florida, USA, in 2003.

## Acknowledgements

We wish to thank ABCL staff members Jeff Makinson, Ryan Zonneveld and Dalio Mira for their assistance with field collections and observations, and Dr R. J. Gagné (USDA-ARS) for identification of specimens.

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**NOTES ON THE GENUS-GROUP PLACEMENT OF  
*PENEPAROXyna* HARDY & DREW AND *SORAIDA* HERING  
(DIPTERA: TEPHRITIDAE: TEPHRITINAE)**

D.L. HANCOCK

PO Box 2464, Cairns, Qld 4870

**Abstract**

The Australian genus *Peneparoxyna* Hardy & Drew is transferred from the *Tephritis* group to the *Campiglossa* group of genera in tribe Tephritini, while the Indonesian genus *Soraida* Hering is newly placed in the *Campiglossa* group.

***Peneparoxyna* Hardy & Drew**

*Peneparoxyna minuta* Hardy & Drew, known from New South Wales and the Northern Territory (Hardy and Drew 1996), was placed in the *Tephritis* group of genera by Hancock (2001) and Hancock and Drew (2003), largely on the basis of its superficial resemblance to *Actinoptera* Rondani. However, the narrow, geniculate mouthparts, weakly reticulate wing pattern and internal structure of the male distiphallus are more consistent with the *Campiglossa* group of genera (especially *Dioxyna* Frey, *Desmella* Munro and *Tanaica* Munro: see Merz and Dawah 2005), to which it is transferred.

***Soraida* Hering**

*Soraida tenebricosa* Hering, known from Lombok and Sunda Is in Indonesia (Hering 1941), was included in the tribe Tephritini by Hardy (1988) but its precise relationships remained unresolved. It differs from all other Indo-Australian members of the subfamily Tephritinae in its wing pattern, being smoky-grey to pale brownish with a pale brown pterostigma but without hyaline markings. Its generic characters (see Hardy 1988), particularly the geniculate mouthparts, are typical of the *Campiglossa* group of genera to which it is referred. *Soraida* and *Peneparoxyna* are the only known genera of the group restricted to the Indo-Australian Region.

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**SONGS AND CALLING BEHAVIOUR OF *FROGGATTOIDES*  
*TYPICUS* DISTANT (HEMIPTERA: CICADOIDEA: CICADIDAE),  
A NOCTURNALLY SINGING CICADA**

A. EWART<sup>1</sup> and L.W. POPPLE<sup>2</sup>

<sup>1</sup>Queensland Museum, PO Box 3300, South Brisbane, Qld 4101

<sup>2</sup>School of Integrative Biology, The University of Queensland, St Lucia, Qld 4072

**Abstract**

The nocturnal male singing behaviour and songs of *Froggattoides typicus* Distant are documented, based on observations and sound recordings made at the Southwood National Park in southern Queensland, during early December 2005, in an open net after dusk. Two distinct song components are recognized: (i) a continuous, soft clicking song (calling song) with some accompanying clicks and click phrases, emitted during the earlier part of the evening and believed to be predominantly timbal produced; (ii) sets of multiple ticks produced during the later part of the evening, commonly accompanying wing flicking behaviour and together with sporadically emitted, short, sharp buzz phrases which sound similar to the sudden expulsion of air from a restricted nozzle.

**Introduction**

Known by its popular name 'eastern bent-winged cicada' (Moulds 1990), *Froggattoides typicus* Distant is a very distinctive, predominantly pale green, endemic Australian cicada. Moulds (1990) noted that it had never been heard singing, at least during the day. It is, however, frequently captured at light, usually arriving well after sunset, when it commonly appears in significant numbers and often emits a marked clicking noise. As noted by Moulds (1990), hand-held specimens of both sexes produce an audible clicking noise, apparently resulting from a rapid beating together of the distal half of the wings while closed. The production of click sounds in this species may, however, also involve an alternative mechanism as the wings are flicked open, generated when the forewing leaves the wing grooves on the margins of the mesonotum (Ewing 1989; see also Gogala and Trilar 2003).

*F. typicus* occurs widely throughout southern, southwestern and central Queensland, being noticeably common in forest communities associated with brigalow (*Acacia harpophylla*) and gidyea (*A. cambagei*) woodlands. It is very rarely seen during the day, sitting camouflaged in tree foliage. We were initially alerted to the nocturnal behaviour of *F. typicus* by observations made of insects calling after 2000 h on the highway between Charleville and Cunnamulla, southern Queensland (S. Peck, pers. comm.). Our observations indicate that it is indeed nocturnally active, with song production only after dusk. Such behaviour is unusual within known Australian Cicadidae, which predominantly sing during the day and/or at dusk (see Moulds 1990).

**Materials and methods**

Observations and recordings were collected in brigalow forest in the Southwood National Park (~27°50'S 150°06'E), southern Queensland,

between 5-9 December 2005. Recordings were made with a Sony cassette recorder WM-D6C, with Sennheiser microphone K6/ME66. Song analyses utilised Avisoft SASLab Pro4 software. After capture at light, the insects were placed in a cylindrical net cage (36 cm x 30 cm diameter), containing small fragments of local vegetation, and placed in a canvas tent (3 x 2 x 2 m) with no artificial lighting but with one window uncovered to allow entry of filtered weak moonlight. Some of the insects were kept alive in the net cage during the following day under strongly shaded conditions. Song and timbal terminology follows that used by Ewart (2005). Amplitude spectra were produced using a 556-point Fast Fourier Transform with Hamming window.

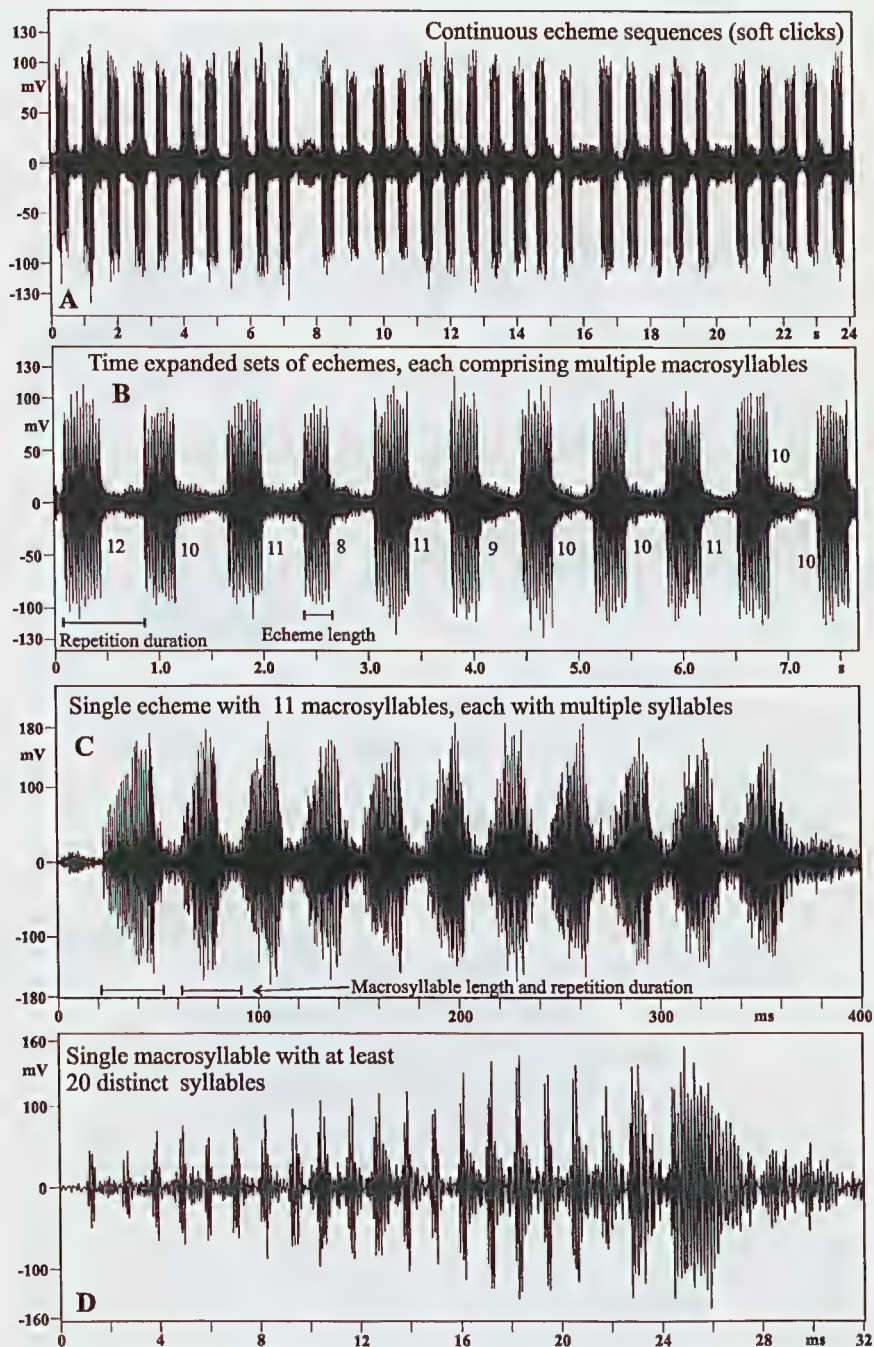
### Singing behaviour

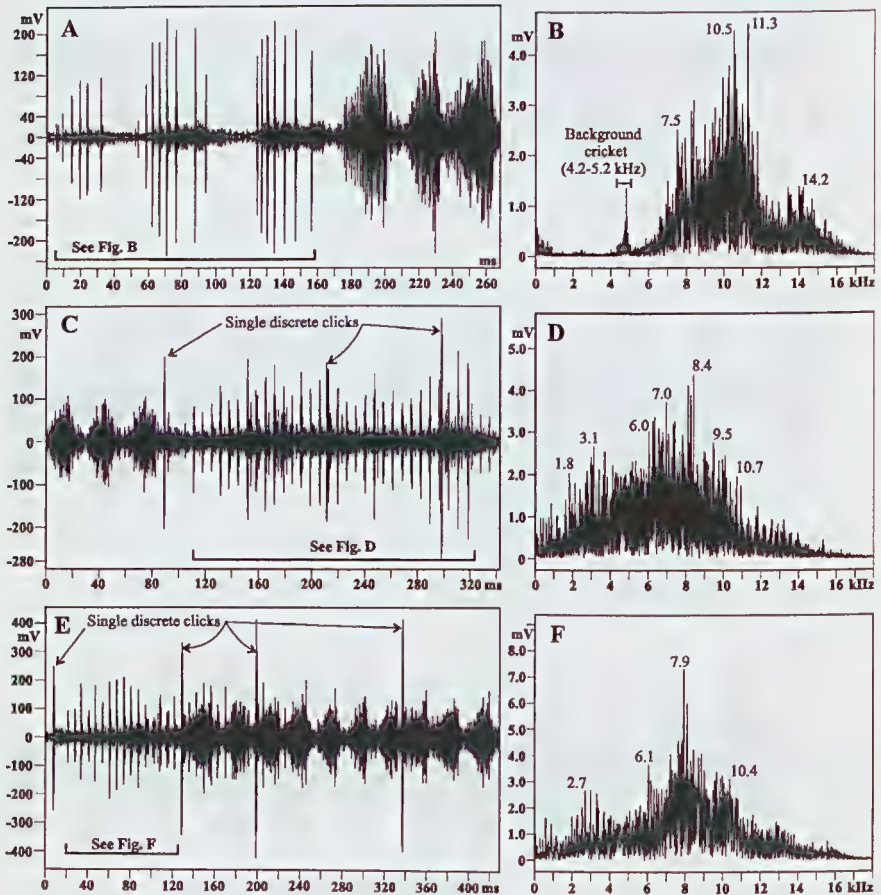
During and especially after dusk the cicadas became active, constantly moving around the vegetation with frequent wing 'flicking'. This activity continued until or slightly beyond midnight. The nature of 'song' production, however, changed between the earlier and later parts of the evening. During the observation period, sunset and end of civil twilight occurred at approximately 1848 h and 1915 h (Eastern Standard Time) respectively. From approximately 2030-2115 h the cicadas, while still actively walking around the vegetation in the cage, produced a continuous, soft clicking song (Fig. 1), sporadically interspersed with sets of regularly emitted and regularly spaced clicks as well as short, sharp and relatively loud individual clicks (Figs 2A-C), in some cases visibly associated with wing flicking. After approximately 2115 h, the soft clicking song became progressively more subdued and ceased. Instead, the cicadas continued to be active, constantly (but erratically) flicking their wings, which produced very short sets of distinct multiple clicks (Fig. 3A), not exactly the same in structure as those emitted earlier, together with additional and very sporadic short sharp 'buzz' phrases (Fig. 3D); this activity continued to slightly beyond midnight. All song types recorded during this study were produced by male insects only.

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**Fig. 1.** Waveform plots (amplitude versus time) of the early evening calling song of *Froggatoides typicus*. (A): the continuous echeme sequences, each echeme sounding as a soft click; the low amplitude phrases occurring between some of the echemes are due to the songs of other *F. typicus* in the background; recording filtered (IIR) to 5.5 kHz. (B): expanded time plot showing the multiple macrosyllables comprising each echeme, the numbers associated with each echeme showing the numbers of macrosyllables present; the definitions of echeme lengths and repetition rates are shown [as also in A]. (C): further time expanded plot of a single echeme showing individual macrosyllables, each comprising multiple syllables. (D): details of individual syllables within the initial macrosyllable shown in Fig. C; also note the long final syllable, possibly indicating syllable coalescence. Records B to D filtered (IIR) to 1 kHz.







**Fig. 2.** Waveform plots (A, C, E) and their respective amplitude spectra (B, D, F; amplitude vs frequency) of early evening clicking sounds of *Froggatoideus typicus*. (A-B): three groups of single clicks, each group with changing repetition rates, emitted between calling song echeme; individual clicks have broadband frequency spectra with dominant frequencies between 8.4 and 11.0 kHz; amplitude spectrum shown is based on all three groups. (C-F): temporally patterned clicks emitted at beginning and end of a sequence of calling song echemes; individual clicks include both single and double pulses; additional higher amplitude isolated single clicks are shown, which may not have been emitted by the same insect; these clicks are single pulses, with narrowband frequency spectra and dominant frequencies between 6.9 and 7.9 kHz.

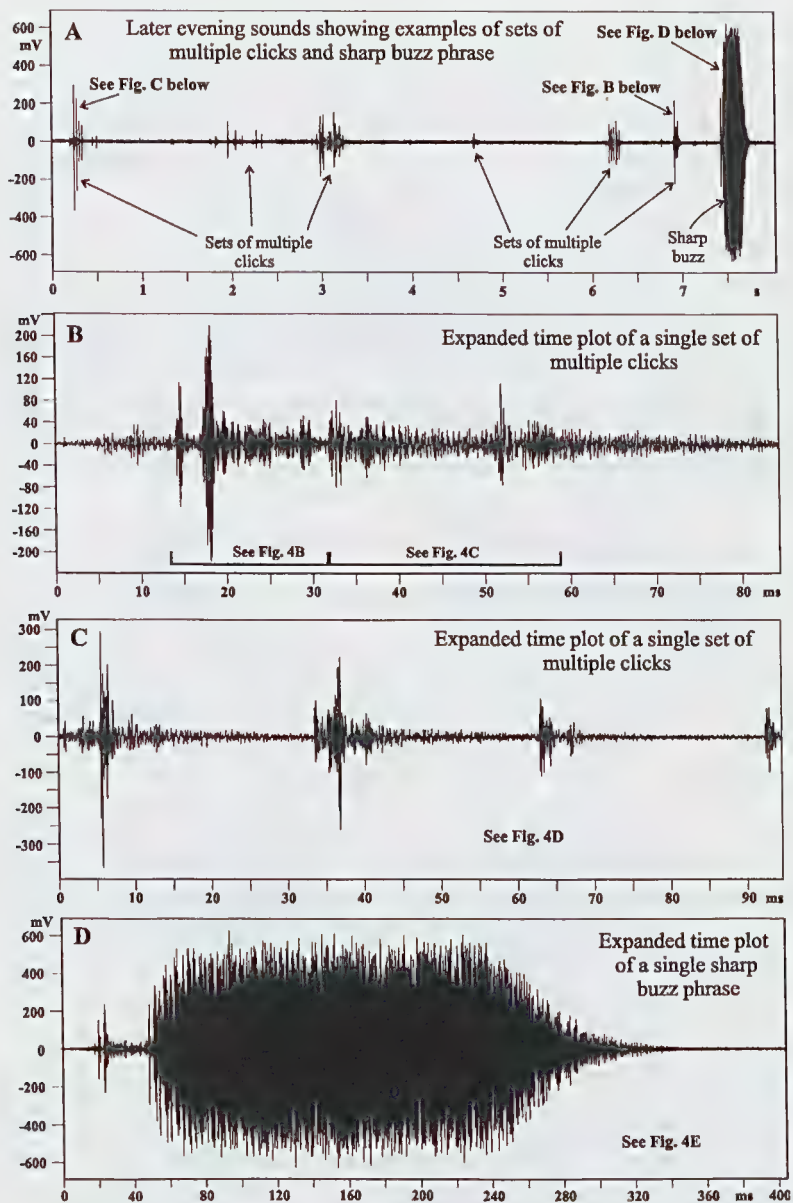


Fig. 3. Waveform plots of later evening clicks and 'buzz' sounds of *F. typicus*. (A): sets of multiple sets of clicks and the short sharp 'buzz' phrase. (B-C): time expanded plots of two sets of clicks shown in Fig. A. (D): expanded time plot of the single sharp 'buzz' phrase shown in Fig. A. Recordings A to D filtered (IIR) to 1 kHz.



## Song analyses

### (a) *Early evening continuous soft clicking song* (Fig. 1)

This consisted of continuous echeme sequences, each echeme producing a single audible click. The mean repetition rate was  $1.35\text{ s}^{-1}$  (range 1.2-1.5) and mean echeme length was 325 ms (range 267-378). Each echeme, as seen in expanded time plots (Figs 1B-C), comprised a sequence of macrosyllables, 8-12 in number, with a mean length of 21.7 ms (range 16.4-30.3), the variation reflecting the number of component macrosyllables. Macrosyllable repetition rates varied from  $24\text{--}37\text{ s}^{-1}$  (27.9-41.5 ms). The initial macrosyllable in each echeme was the longest. Each macrosyllable was further resolved, at further time expansion (Fig. 1D), into 16-24 discrete syllables. Syllable repetition rates varied from  $295\text{--}2040\text{ s}^{-1}$  (mean 910), equivalent to syllable lengths of 0.49-3.4 ms (mean 1.13); these equated closely to the syllable amplitude modulation of  $885\text{ s}^{-1}$ . The final two high amplitude syllables within each macrosyllable apparently have coalesced, as illustrated by the macrosyllable shown in Fig. 1D.

The amplitude spectrum (Fig. 4A) of the continuous clicking song component shows the emitted frequency maxima to lie between approximately 7 and 9 kHz, with significant frequency peaks, with reduced magnitudes, extending to 16 kHz. The spectrum is notable for the extensive array of apparent sidebands (listed in Fig. 4A), their complexity attributed to the complexity of the fine scale variability within the macrosyllable and syllable structures. Very detailed time plots and amplitude spectra of the syllables (not shown) indicated that the final high amplitude syllables (as shown in Fig. 1D) are characterised by a rather narrow band of frequency emission centred at 7.2 kHz, the frequencies slightly decreasing during syllable emission and rising markedly either side of the syllable. In contrast, the initial 5 syllables shown in Fig. 1D had frequencies between 9.4 and 10.1 kHz, compared with the low amplitude inter-syllable regions which exhibited higher frequencies between 10.6 and 11 kHz. These demonstrate rapid temporal changes in frequencies during syllable emission, on time scales of  $<1\text{ ms}$ .

### (b) *Early evening click phrases and single clicks*

Short phrases, less than 300 ms in length and comprised of temporally structured clicks, were observed to be sporadically interspersed within, or between, the echemes of the continuous soft clicking song (Fig. 2). The regularly emitted click phrases (Figs 2C-D) had click repetition rates of  $145\text{--}146\text{ s}^{-1}$  and comprised both single and doublet pulses. When emitted as short groups of clicks (each single pulses: Fig. 2A), the click repetition rates decreased during emission. The frequency structures of these structures click phrases are variable (Figs 2B, D, F), ranging from relatively sharply tuned frequency maxima near 8 kHz (Fig. 2F), to more broadband frequency maxima between about 8 and 11.5 kHz (Fig. 2A), to very broadband frequency distributions between 2 and 11 kHz (Fig. 2D).

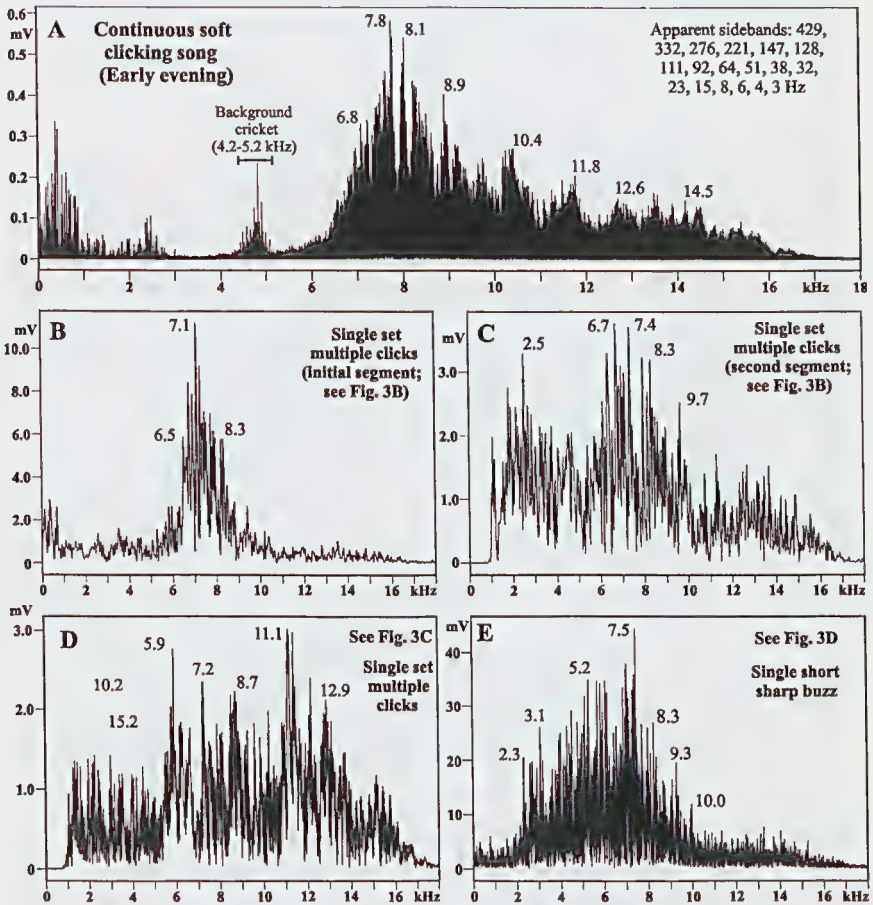


Fig. 4. Amplitude spectra of *Froggatoides typicus* songs. (A): multiple echemes (40 seconds) of the continuous soft calling song shown in Fig. 1A; note the weak background song of an unidentified cricket between 4.2 and 5.1 kHz. (B-C): initial and later segments, respectively, of the set of clicks shown in the expanded time plot in Fig. 3B. (D): set of multiple clicks shown in the expanded time plot in Fig. 3C. (E): The short 'buzz' phrase shown on Fig. 3D. Spectra shown in Figs C and D filtered (IIR) to 1 kHz.

The relatively higher amplitude sharp single clicks (Figs 2C, E) are emitted apparently randomly during the continuous soft clicking song. Expanded time plots (not shown) showed these to be narrowly tuned single pulses with relatively narrow dominant frequency spectra between 6.9 and 7.9 kHz. Those shown in Figs 2C-D may not all emanate from a single insect in the cages.

*(c) Later evening sets of multiple clicks (Fig. 3A)*

These are here linked to wing 'flicking' behaviour accompanying the constant walking activity. The timing between the sets of clicks was very variable although they were emitted frequently. Individual sets of clicks varied in detailed structure, as seen in expanded time plots (Figs 3B-C). Within a given set, individual clicks ranged from 2 to 12 in number. Their structures also varied, some comprising high amplitude pulses with logarithmically decaying tail, others that were relatively closely spaced and partially coalescing, with extended complex decaying tail (Fig. 3B). The initiation of the high amplitude pulse trains of the clicks were mostly abrupt and were commonly preceded (~5-10 ms interval) by a sharp, low amplitude pulse or pulses. The two sets of amplitude spectra illustrated (Figs 4B-D) exhibit strongly contrasting frequency patterns, particularly in the click sequence shown in Fig. 3B. The initial segment of this sequence had a narrowband frequency structure between 6.5 and 8.5 kHz (Fig. 4B). The following segment of the click sequence (Fig. 4C) exhibited broadband frequency emissions between  $\leq 1$  and 10 kHz, extending with reduced amplitude to 15 kHz. The most significant difference between these two spectra was the presence of a strong lower frequency component below 5 kHz in the later segment of the ticking sequence, which we attribute to wing flicking (see below). The amplitude spectrum of the click sequence shown in Fig. 3C exhibits an extremely broad frequency emission extending between  $\leq 1$  and 16 kHz (Fig. 4D).

*(d) Later evening short sharp 'buzz' phrases (Fig. 3D)*

These clearly differ from the sets of clicks previously described. Those measured ranged between 0.3 and 0.35 s in length. They are abrupt, relatively loud and emitted only sporadically and irregularly. To the human ear, they have a distinct resemblance to the sudden expulsion of air from a restricted nozzle. As shown by the waveform plots (Fig. 3D), they initiate abruptly, continue briefly at constant amplitude and decay nearly exponentially. A small precursor double pulse is present. The amplitude spectra showed a broad frequency emission range between approximately 2 and 10 kHz, with maxima near 7-7.5 kHz (Fig. 4E). There appeared to be an absence of clearly defined temporal patterning and thus the overall structure was similar to white noise. The small precursor pulse phases exhibited a very narrowly tuned spectrum between 6.7 and 8.1 kHz, quite distinct from that of the main phrase.



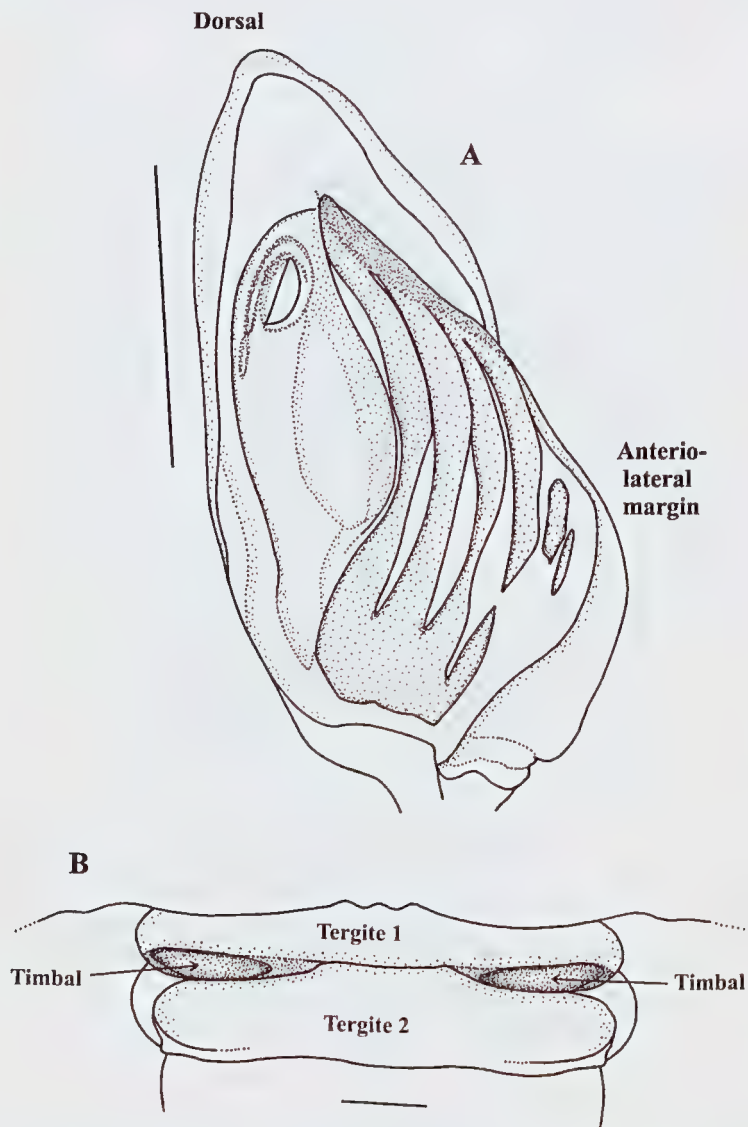
## Discussion

The early evening continuous soft clicking song is interpreted as a timbal-generated calling song with a dominant frequency range between ~6.5 and 9 kHz. Although a cursory examination of the timbals suggest that they are poorly developed, this is only because they are effectively 'sandwiched' between the bulbous tergites 1 and 2 (Figs 5B, 6B) and require the removal of much of tergite 2 to be fully visible (Fig. 5A). They are similar in overall form to those of diurnally singing cicadas. The six timbal ribs (long ribs) are very pale green in colour and weakly sclerotised. The four posterior ribs (1 to 4) are fused dorsally to the basal spur and ventrally to each other. Ribs 1 to 3 are continuous across the timbal, whereas rib 4 is discontinuous medially. The two most anterior ribs (5, 6) are short, unfused and appear to represent remnant long ribs. No inter-rib sclerites between ribs 1 to 4 were observed. The dorsal and ventral fusion of ribs 1 to 4 suggest that these may act as a single rib during timbal contractions and relaxation, as suggested in certain diurnal ticking cicadas (Ewart 2005). The male opercula are well developed and also similar in overall structure to those of diurnal cicadas (Fig. 6A). Those in *F. typicus* are notable for the absence of spikes on the meracantha and the marked curvature and undulations of the surfaces of the opercula, the latter best seen in lateral profile (Fig. 6B).

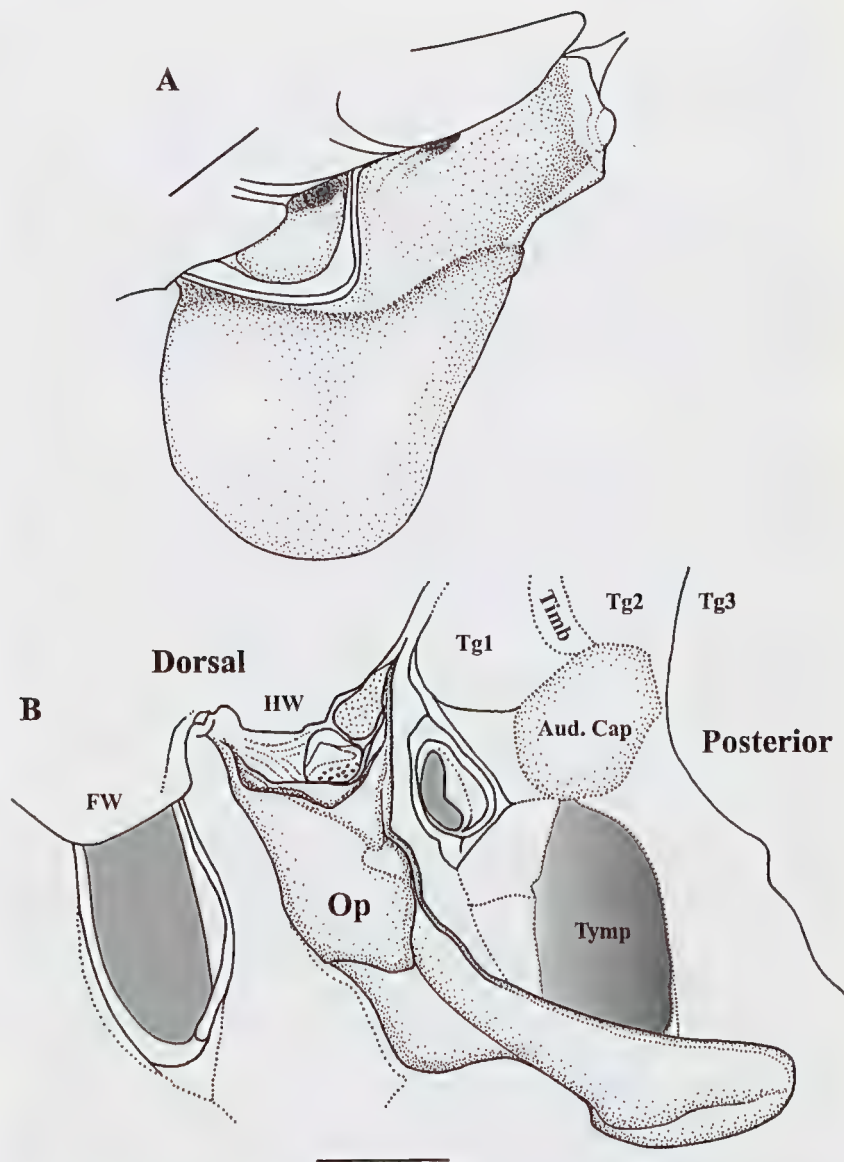
The various clicking sounds shown above exhibit complex frequency spectra varying between narrowband and very broadband. As described, wing flicking occurs frequently during early and later evening songs. Some clicks were observed to correlate with wing flicks, suggesting that both timbals and wing flicks are used, either singly or in combination, as part of song production. An additional factor is the differential role of sound radiation structures (timbals, tympana and abdomen) in modulating the frequency signatures of the emitted sounds (Fonseca and Popov 1994).

We suggest that the earlier evening songs are predominantly timbal produced, including the patterned and separate click components, which we further correlate with dominant spectral frequencies between approximately 6-11 kHz (e.g. Figs 2B, 2F; 4A, 4B). Nevertheless, many clicks have dominant frequencies which include a significant component at <6 kHz and in some clearly extend to >11 kHz (e.g. Figs 4C-D). We interpret these clicks and their spectral frequencies to have originated predominantly through wing flicking. The later evening clicks are mainly, but not entirely, of these types. Nevertheless, amplitude spectra of some clicks, including early and later evening types, showed frequencies which suggest the presence of both timbal and wing clicking components (e.g. Figs 2D, 4B-C), pointing to combined timbal and wing flicking in sound production. The short sharp 'buzz' phrases are enigmatic in their origin. Both their structure, as seen in the waveform plots, and their frequency spectra distinguish them from the other sounds produced by *F. typicus*, implying a different production mechanism. As noted

above, the sound resembles a sharp expulsion of air. The frequency spectrum of the precursor pulses, however, suggests that these may initiate via a timbal origin.



**Fig. 5.** *Froggattoides typicus*. (A): view of right timbal. (B): view of dorsal surface between tergites 1 and 2 showing the position of the timbals 'sandwiched' between the tergites. Scale bars = 1 mm.



**Fig. 6.** *Froggattoides typicus*. (A): ventral surface of left operculum. (B): lateral view of left operculum (Op) and proximal structures. Tymp = tympanum (graded shading); Aud Cap = auditory capsule; FW and HW = bases of fore and hind wings; Tg 1-3 = tergites 1, 2 and 3; Timb = timbal ('sandwiched' between tergites 1 and 2). Two external openings are shown as the shaded areas. Scale bars = 1 mm.



*Froggattoides typicus* seemingly exhibits certain behavioral and song adaptations to nocturnal activity. First is the constant movement at night within tree foliage, observed as walking in the cages, but is also inferred to include at least short flights in the natural environment (noting their ready attraction to light). This activity starts during dusk, again based on observations on caged specimens. A second aspect is the soft continuing clicking song, here identified as the calling song, emitted during the earlier part of the evening. This song has a dominant frequency range of 6.5–9 kHz, with a weaker extension to about 14 kHz. Additional patterned and single clicks are emitted during this song component, whose frequencies overlap, even slightly extending the range of the continuous calling song. These early evening songs are inferred to be predominantly timbal produced, although some clicks seem to have a wing-flicking component.

The third aspect is the change towards the increasing importance of clicking songs later in the evening, tending to differ in their structures and frequency properties from those emitted earlier. These clicks appear to be produced predominantly through wing flicking, although some have a timbal component. Sound production is again accompanied by movements of the cicadas. These clicks, as described, have very wide frequency ranges, from <2 to ~16 kHz, believed to facilitate sound transmission and localisation. Wing flicking may also be associated with pheromone dispersal, although this remains to be demonstrated. A fourth aspect is the production of the sporadic short, sharp 'buzz' song, which occurs both in the early and especially later evening. The dominant frequency of this component lies between approximately 2 and 10 kHz, thereby effectively complementing the frequency ranges of the other emitted sounds.

A fifth aspect concerns sound interference during nocturnal singing. During the period of the present observations, the only interference encountered was a continuous song of an unidentified cricket. The frequency of this song lies within the narrow range of 4.2–5.1 kHz (Fig. 4A). This is below the dominant frequency of the *F. typicus* calling song and only minimally overlaps with that of the other two song types.

One significant feature of the variety of sounds emitted by *F. typicus* is their resulting broad frequency range. Such frequency ranges are expected to facilitate more efficient survival of song structures which are degraded through absorption, scattering, reflection and refraction, which lead to frequency filtering of sound propagating through foliage (Michelsen 1992, Richards and Wiley 1980, Michelsen and Larsen 1983, Römer and Lewald 1992). The higher frequency components should also aid in sound localisation (Gerhardt and Huber 2002). It is suggested that the early evening calling songs and clicking sounds function to alert and attract females to the presence of males within a given area. The later evening clicking and 'buzz' sounds may facilitate the final stages of localisation of both males and

females. It is likely that females also use wing flicking to respond to male calls (given that female *F. typicus* also possess strongly angulated forewings), as has been observed in a number of diurnal cicada species (Sueur and Aubin 2004).

### Acknowledgements

Thanks are due to the Rangers and Officers of the Southern Region of the Queensland Parks and Wildlife Service, especially Stephen Peck for alerting us to the night songs of *F. typicus* and Rod Hobson for organising a fauna survey of the Southwood National Park, during which the above observations were made. Dr M.S. Moulds, two anonymous referees and Kathy Hill and D. Marshall (University of Connecticut, U.S.A.) are thanked for their constructive comments and observations on the manuscript.

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# THE AUSTRALIAN ENTOMOLOGIST



VOLUME 34

2007

Published by:

THE ENTOMOLOGICAL SOCIETY OF QUEENSLAND

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*The Australian Entomologist* is a non-profit journal published in four parts annually by the Entomological Society of Queensland. The journal is devoted to entomology of the Australian region, including New Zealand, Papua New Guinea and islands of the south-western Pacific. Articles are accepted from amateur and professional entomologists. The journal is produced independently and subscription is not included with membership of the Society.

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ISSN 1320-6133

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# THE AUSTRALIAN ENTOMOLOGIST

## Contents

### Volume 34, 2007

#### ATKINS, A.

- Notes on the distribution and biology of *Trapezites genevieveae* Atkins, *Signeta tymbophora* (Meyrick & Lower) and *Hesperilla sarnia* Atkins (Lepidoptera: HesperIIDae) 121

#### EWART, A. and POPPLE, L.W.

- Songs and calling behaviour of *Froggattoides typicus* Distant (Hemiptera: Cicadoidea: Cicadidae), a nocturnally singing cicada 127

#### FERGUSON, D.J.

- Field observations of *Perissomma mcalpinei* Colless (Diptera: Perissommatidae) 93

#### GINN, S.G., BRITTON, D.R. and BULBERT, M.W.

- New records of butterflies (Lepidoptera) in the Pilbara region of Western Australia, with comments on the use of malaise traps for monitoring 65

#### HANCOCK, D.L.

- Phylogeny of the troidine butterflies (Lepidoptera: Papilionidae) revisited: are the red-bodied swallowtails monophyletic? 33

- The identity of '*Trypeta*' *nigricans* Wiedemann (Diptera: Tephritidae: Tephritinae) 49

- A new synonym and a new combination in the fruit fly tribe Pliomelaenini (Diptera: Tephritidae: Tephritinae) 57

- A note on the genus *Hemiristina* Permkam & Hancock (Diptera: Tephritidae: Trypetinae) 84

- A review of the fruit fly tribe Eutretini (Diptera: Tephritidae: Tephritinae) in the Indo-Australian region 92

- A review of *Callistomyia* Bezzi and related genera (Diptera: Tephritidae: Trypetinae) 107

- The identity of *Terellia immaculata* Macquart (Diptera: Tephritidae: Tephritinae) 119

- Notes on the genus-group placement of *Peneparoxyina* Hardy & Drew and *Soraida* Hering (Diptera: Tephritidae: Tephritinae) 126

#### HARDY, N.B. and GULLAN, P.J.

- A new species of *Phacelococcus* Miller (Hemiptera: Coccoidea: Eriococcidae) on *Bursaria* (Pittosporaceae) 85

#### HOPKINSON, M. and HOPKINSON, A.

- A range extension for *Graphium aristeus parmatum* (Gray) (Lepidoptera: Papilionidae) in northern Queensland 76

#### JOHNSON, S.J. and VALENTINE, P.S.

- A new subspecies of *Jalmenus inous* Hewitson (Lepidoptera: Lycaenidae) from Shark Bay, Western Australia 77



<b>KOHOUT, R.J.</b>	
A new species of the subgenus <i>Polyrhachis</i> ( <i>Cyrtomyrma</i> ) Forel (Hymenoptera: Formicidae: Formicinae) from Borneo	115
<b>LAMBKIN, T.L.</b>	
The immature stages of <i>Cephrenes moseleyi</i> (Butler) (Lepidoptera: Hesperiiidae) from Torres Strait, Queensland	51
<b>LAMBKIN, T.L. and KNIGHT, A.I.</b>	
Confirmation of <i>Euploea leucostictos</i> (Gmelin) and <i>E. netscheri</i> <i>erana</i> (Fruhstorfer) (Lepidoptera: Nymphalidae) in Torres Strait, Queensland, and the first record of <i>E. tulliolus dudgeonis</i> (Grose-Smith) in Australia	15
<b>MAGINNIS, T.L. and MAGINNIS, L.P.</b>	
Leg autotomy and regeneration in a population of <i>Didymuria violascens</i> (Leach) (Phasmatodea: Phasmatidae) in New South Wales, Australia	27
<b>MOUND, L.A. and TREE, D.J.</b>	
Oriental and Pacific Thripidae (Thysanoptera) new to Australia, with a new species of <i>Pseudodendrothrips</i> Schmutz	7
<b>OLIVE, J.C.</b>	
A new species of <i>Gudanga</i> Distant (Hemiptera: Cicadidae) from northern Queensland	1
<b>PURCELL, M., WINEWRITER, S. and BROWN, B.</b>	
<i>Lophodiplosis trifida</i> Gagné (Diptera: Cecidomyiidae), a stem-galling midge with potential as a biological control agent of <i>Melaleuca quinquenervia</i> (Myrtaceae)	123
<b>SMITH, A.B.T.</b>	
Review of the genus <i>Dungoorus</i> Carne (Coleoptera: Scarabaeidae: Rutelinae: Anoplognathini)	43
<b>WHITEHOUSE, M.E.A. and GRIMSHAW, J.F.</b>	
Distinguishing between lynx spiders (Araneae: Oxyopidae) relevant to IPM in cotton in the Namoi Valley, New South Wales	97
<b>BOOK REVIEWS</b>	56, 58, 61
<b>RECENT LITERATURE</b>	63, 140

Publication dates:	Part 1 (pp 1-32)	1 March 2007
	Part 2 (pp 33-64)	25 May 2007
	Part 3 (pp 65-96)	10 September 2007
	Part 4 (pp 97-140)	10 December 2007

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THE AUSTRALIAN  
**Entomologist**

Volume 34, Part 4, 10 December 2007



CONTENTS

---

**ATKINS, A.**

Notes on the distribution and biology of *Trapezites genevieveae* Atkins,  
*Signeta tymbophora* (Meyrick & Lower) and *Hesperilla sarnia*  
Atkins (Lepidoptera: Hesperidae).

121

---

**EWART, A. AND POPPLE, L.W.**

Songs and calling behaviour of *Froggattoides typicus* Distant  
(Hemiptera: Cicadoidea: Cicadidae), a nocturnally singing cicada.

127

---

**HANCOCK, D.L.**

A review of *Callistomyia* Bezzi and related genera (Diptera: Tephritidae: Trypetinae).

107

---

**HANCOCK, D.L.**

The identity of *Terellia immaculata* Macquart (Diptera: Tephritidae: Tephritinae).

119

---

**HANCOCK, D.L.**

Notes on the genus-group placement of *Peneparoxyna* Hardy & Drew and  
*Soraida* Hering (Diptera: Tephritidae: Tephritinae).

126

---

**KOHOUT, R.J.**

A new species of the subgenus *Polyrbachis* (*Cyrtomyrma*) Forel  
(Hymenoptera: Formicidae: Formicinae) from Borneo.

115

---

**PURCELL, M., WINEWRITER, S. AND BROWN, B.**

*Lophodiplosis trifida* Gagné (Diptera: Cecidomyiidae), a stem-galling midge with  
potential as a biological control agent of *Melaleuca quinquenervia* (Myrtaceae).

123

---

**WHITEHOUSE, M.E.A. AND GRIMSHAW, J.F.**

Distinguishing between lynx spiders (Araneae: Oxyopidae) relevant  
to IPM in cotton in the Namoi Valley, New South Wales.

97

---

**RECENT ENTOMOLOGICAL LITERATURE**

140

---